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Change of Structure in the Solid State.

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Besides the changes which occur when a metal or alloy passes from the liquid to the solid state, there are those which take place after solidification.

(1) Change of structure due to mechanical stress and the growth of crystals on annealing the metal or alloy thus strained. This subject has been carefully studied by Ewing and Rosenhain * and others.

(2) Due to change in composition in the solid—diffusion. Under this heading we have carburization † (cementation, case-hardening, etc.): decarburization ‡ (and change of

* Phil. Trans. Royal Society, 195, p. 279, and 193, p. 353.

† Arnold. *Journal I. and S. Inst.*, II, 1898, p. 185.

‡ Stead. *Proc. Cleveland Inst. Eng.*, Dec., 1895, p. 79.

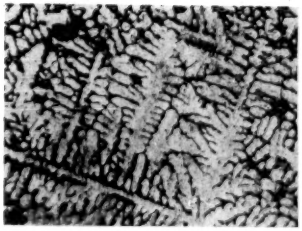

FIG. 1. × 35. V.

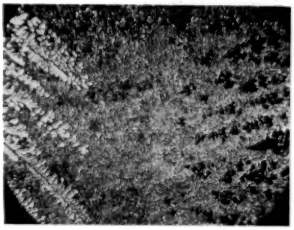

FIG. 2. × 20. V.

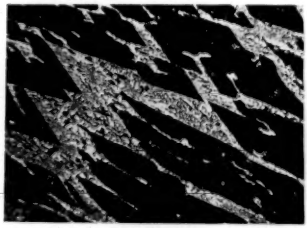

FIG. 3. × 30. O.

FIG. 4. × 35. V.

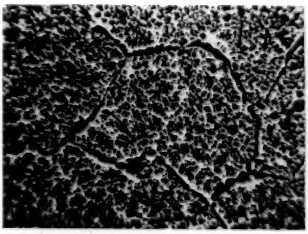

FIG. 5. × 16. V.

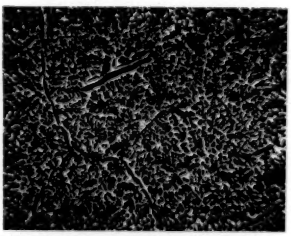

FIG. 6. × 35. V.

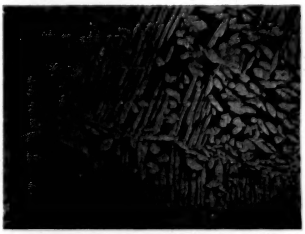

FIG. 7. × 35. V.

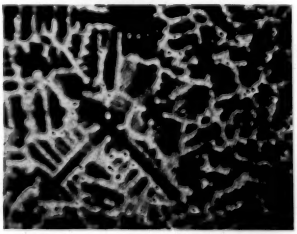

FIG. 8. × 16. V.

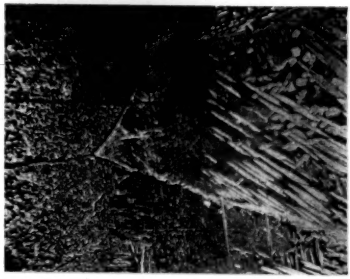

FIG. 9. × 35. V.

FIG. 10. × 35. V.

FIG. 11. × 33 V.

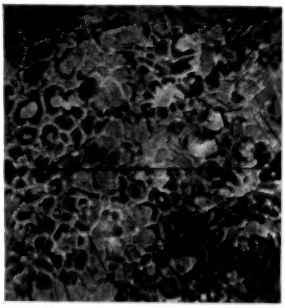

FIG. 12. × 33. V.

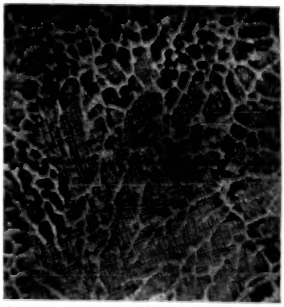

FIG. 13. × 35. V.

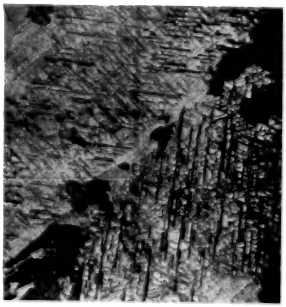

FIG. 14. × 33. V.

carbon from the combined to the free state, or from cementite to graphite, *e. g.*, malleable cast iron): passage of one metal into another, as gold into lead:* oxidation, as the formation of alloys of copper and oxide of copper in the solid.†

(3) Changes which occur in the solid with change of temperature, such as the change of pure iron from one state or allotropic modification into another‡ (α, β and γ). *The change of structure in the solid state* which occurs when certain alloys cool down from their point of solidification to the normal temperature. Such changes are found in the alloys of copper and aluminum, of copper and tin, of copper and antimony, of iron and steel, etc.

Copper and Aluminum.—In the alloys of copper and aluminum, Le Chatelier has found at least three compounds, viz.: Al_2Cu, $AlCu$ and $AlCu_3$.

From pure aluminum to Al_2Cu we have a simple series, whose freezing-point curve is composed of two inclined branches, intersecting at the eutectic alloy (about 32 per cent. Cu). As we pass from the aluminum end to the alloy with 31 per cent. Cu, we find dendrites and grains of aluminum set in an increasing eutectic or groundmass, which freezes at about 530° C.

Fig. 1, magnified 35 diameters, vertically illuminated, shows the alloy containing 23 per cent. Cu, in which part of a large dendrite of aluminum is seen surrounded by the eutectic. This eutectic is seen in places to be composed almost entirely of Al_2Cu, because, during solidification, its aluminum has migrated to and merged with that composing the grains and dendrites. As Stead has pointed out, this is of common occurrence in many eutectics. It is specially marked in the case of the copper-rich or silver-rich alloys of the copper-silver series.

From 32 per cent. Cu to Al_2Cu, we find this compound crystallizing out in decreasing amounts of the eutectic.

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* Phil. Trans. Royal Society, 187 (1896), p. 383.

† Heyn. Inter. Ass. Test. Mat., 1901. (Hofman. T. A. I. M. E. 1903.)

‡ Osmond. "Annales des Mines," Jan., 1900. *Metallographist*, III, 181.

Fig. 3 × 30 diameters oblique illumination shows the 45 per cent. alloy, and may be taken as a type. The structure of the whole series is well shown in a diffusion alloy, made by pouring molten aluminum onto the molten compound, Al_2Cu, and allowing the whole to slowly solidify. *Fig. 2* × 20 ∨ represents the junction between the two. (The top of the alloy is on the left hand of the photomicrograph.) We see dendrites of aluminum growing down into the eutectic alloy, whilst crystals and dendrites of the compound Al_2Cu grow upwards.

When the copper in the alloy is increased above Al_2Cu, the second compound AlCu is found crystallizing out in a groundmass of the first. *Fig. 4* × 35 ∨ shows this structure. The alloy contains 66 per cent. copper, 34 per cent. aluminum. With further increase in copper, the alloys are apparently homogeneous from 78 to above 83 per cent. Cu. Above this point to about 90 per cent. Cu, we find structures in the slowly cooled alloys due to a rearrangement in the solid. *Fig 5* × 16 ∨ is the alloy containing about 85 per cent. Cu, in which dark veins and irregular grains are surrounded by a lighter envelope. If the alloy be raised to a red heat and quenched, a change in structure occurs, and under a low power (33 diameters) the alloy is apparently homogeneous, though with a higher magnification it is seen to be composed of alternate light and dark bodies. On reheating to a red and slowly cooling, the original structure is restored. *Fig. 6* × 35 ∨ shows the same alloy quenched, then reheated and slowly cooled. The structure of *Fig. 5* has been reproduced. As the copper is again increased, the dark constituent disappears, leaving the light body which, under high powers, is seen to possess a eutectic structure. With further additions of copper, bright grains and veins of $AlCu_3$ make their appearance. *Fig. 7* × 35 ∨ shows the 89 per cent. Cu alloy and consists of bright $AlCu_3$ set in a darker groundmass with the eutectic structure. Again, the structure of the series can be well shown by a diffusion alloy between 80 and 90 per cent. copper. Such an alloy is seen in *Fig. 9* × 35 ∨. (The top of the figure is on the left.) Dark dendrites, similar to those in *Fig. 5*, are seen to grow downwards,

whilst the bright $AlCu_3$ grows upwards. The central zone is composed of the alloy having the fine eutectic structure. Between this and the upper part of the alloy, a third constituent sometimes occurs, as long bright needles, etc., but as yet it has not been isolated. Now if the alloy shown in *Fig. 9* be reheated to a red and quenched, the whole mass becomes homogeneous and has the structure seen in *Fig. 10*. This structure closely resembles that of steel quenched from a very high temperature (martensite). On reheating and slowly cooling, the original structure is restored. Although the complete cooling curves for these alloys have not yet been published, there is no doubt that the alloys solidify as homogeneous solid solutions resembling martensite, and at a lower temperature rearrange themselves as shown in *Fig. 9*. The curve due to this rearrangement in the solid will therefore be similar to that of a simple series of alloys forming neither solid solutions nor isomorphous mixtures.

From 92 per cent. Cu onwards, we find the alloys consist of solid solutions (probably of $AlCu_3$ and Cu). *Fig. 8* × 16 ∨ shows the alloy containing 97 per cent. Cu slowly cooled. The copper dendrites are seen to vary in composition from center to outside, and in this they resemble those at the copper end of the CuSn series. It may be, however, that we are not dealing with a compound $AlCu_3$, but with a series of solid solutions whose maximum composition corresponds to $AlCu_3$.

Copper and Tin.—The constitution of the alloys of copper and tin has been carefully worked out by Heycock and Neville.* *Fig. 33* is based on their curve. In a former paper† the structure of the series was shortly set forth, but several points were left open to discussion, because the exact meaning of many of the changes which take place in the solid were not known, my own investigations‡ only explaining some of them.

The curve *A B L C D E G H I K* marks the beginning of crystallization and above this freezing-point curve the alloys

* Bakerian Lecture. *Phil. Trans. R. S.*, Vol. CCII, A., pp. 1–69.
† *Jour. Frank. Inst.*, July–Sept., 1902.
‡ *Proc. Inst. Mech. Eng.* (London), Dec., 1901, pp. 1211–1272.

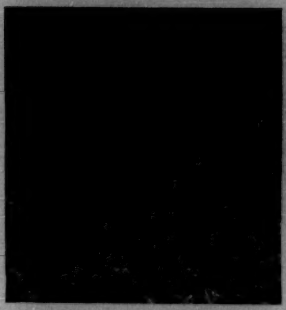

FIG. 15. × 55. V.

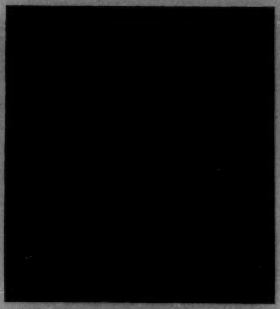

FIG. 16. × 35. V.

FIG. 17. × 33. V.

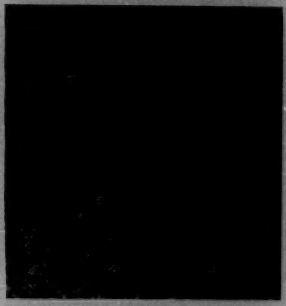

FIG. 18. × 88. V.

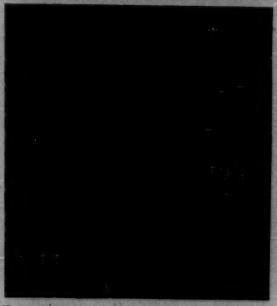

FIG. 19. × 120.

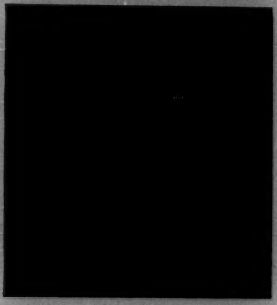

FIG. 20. × 120.

are in the liquid state. Professor Roosebbom calls a curve of this kind the "liquidus." Below the curve $A\,b\,l\,c\,m\,d\,e\,f\text{-}E_2\,E_3\,H'\,H''\,K'$ everything is solid, this being termed the "solidus." Between the two we have a mixture of the solid and liquid states, whose compositions are given by a horizontal line cutting the liquidus and solidus. The horizontal line marks the temperature at which these two phases (liquid and solid) are in equilibrium. Heycock and Neville divide the series into ten groups marked by the points *B*, *L*, *C*, *D*, *E*, *F*, *G*, *H* and *I*.

(1) The alloys occurring between *A* and *B* (100 to 91 per cent. Cu) consist of a uniform solid solution of up to 9 per cent. tin in copper (α) below $A\,b$. Between the liquidus and solidus, they consist of crystals of $\alpha + a$ liquid richer in tin. In the moderately slowly cooled alloys, it is often found that the central parts of the dendrites of α etch differently from the outsides, due to their being richer in copper, and cooling not being slow enough to allow of perfect diffusion to produce uniform composition. Such a structure is seen in *Fig. 8*.

(2) The alloys from 91 to 77·5 per cent. copper or *B* to *L* on passing the liquidus begin to crystallize out dendrites of α; but on reaching the temperature marked by the line $b\,l\,C$ they react with the mother liquor:

α (of composition b) + liquid (of composition C) = β (of composition l) until the whole of it is used up. The substance β is a solid solution containing from 22·5 to 27 per cent. tin. Below $b\,l$, or 790° C., the whole mass is solid, and consists of dendrites of copper containing about 9 per cent. tin in solid solution (a_b) surrounded by a solid solution of composition 77·5 per cent. Cu, 22·5 per cent. Sn (β_1). As the temperature falls from 790° C. ($b\,l$) to 500° C. ($b'\,C'$) the dendrites of α continue to grow at the expense of the solid solution β, whose composition is reduced from 77·5 to 74·5 per cent. Cu. On $b'\,C'$ the residual β breaks up into minute α and Cu_4Sn (δ). In other words, at the temperature $b'\,C'$ (500° C.) the remaining solid solution β is transformed into the eutectoid of copper (containing tin in solid solution) and the compound Cu_4Sn, which is the structure found at the normal temperatures.

(3) The alloys from 77·5 per cent. to 74·5 per cent. copper, or *L* to *C*, on reaching the liquidus begin to separate dendrites and grains of α, but the whole of this is changed into β containing *l* per cent. of copper on reaching the temperature marked by *l C*. The dendrites, etc., of this solid solution β continue to grow, their composition and that of the liquid being given by the solidus *l c* and the liquidus *C D* as before, until the whole is a solid solution below *l c*. On reaching the temperature of the curve *l C'*, however, the solid solution β becomes saturated with α, which crystallizes out as in the alloys under (2). Then when the temperature marked by the line *b' C'* is reached, the remaining β is resolved into the eutectoid of α and δ or copper (with tin in solid solution) and Cu_4Sn.

(4) The alloys from 74·5 per cent. to 68·2 per cent. copper comprise the series from *C* to *D*, or from the eutectoid to the compound Cu_4Sn. On reaching the liquidus *C D* they separate out the solid solution β, but when less than *e* per cent. copper is present they are changed into the solid solution γ on reaching the temperature *e m D*. Below the solidus the whole mass is a solid solution, until the temperature of the curve *D'X'* is reached, when the compound Cu_4Sn or δ separates out as veins and irregular grains or rosettes. The compound continues to separate out until the temperature *X* D_2 is reached, when the remaining solid solution splits up into the eutectoid of $\alpha + \delta$ as before.

As Heycock and Neville have pointed out,* the surfaces of these alloys are covered with large dendrites due to the initial crystallization. If the surface is polished, it is at once seen that they have re-arranged themselves, and are now built up of the compound Cu_4Sn and the eutectoid. *Fig. 15* × 55 ∨ shows such a polished surface in the alloy containing 73 per cent. copper, in which the composite nature of the primary crystallization is seen. *Fig. 16* × 35 ∨ shows the same alloy quenched at the solidification point, and shows the dark dendrites of the solid solution β set in the lighter groundmass richer in tin. *Fig. 17* × 33 ∨

* *Proc. Royal Society*, Vol. XCVI.

shows the same alloy slowly cooled to 650° C. and quenched. The alloy is not homogeneous throughout, but parts have been resolved into a light and dark constituent. It may be that we have a partial separation of the compound Cu_4Sn due to the quenching being too slow. *Fig. 18* × 88 ∨ shows the very slowly cooled alloy in which the bright Cu_4Sn has separated out of the solid solution as veins and rosettes, whilst under a higher power the darker groundmass is seen to be composed of the eutectoid.

(5) The alloys from 68·2 per cent. to 61·6 per cent. copper, or from *D* to *E*, pass from the compound Cu_4Sn to the compound Cu_3Sn. On reaching the curve *D E*, dendrites of the solid solution γ crystallize out until the whole mass is solid. When the temperature reaches the curve *E′ D′*, the compound Cu_3Sn separates out (η) until at the temperature *D′ E″* the residual γ has the composition of 68·2 per cent. Cu, when it is transformed into δ, or the compound Cu_4Sn. *Fig. 12* × 33 ∨ shows the alloy containing 66 per cent. Cu 34 per cent. Sn quenched just before solidification, and is composed of cells of the solid solution γ. *Fig. 13* × 35 ∨ shows the same alloy quenched on the solidus, and is composed of almost uniform γ. *Fig. 14* × 35 ∨ shows the alloy quenched between the solidus and *E′ D′*. All trace of the cell-like structure has gone, and we have large grains of γ, with a curious linear structure (seen also in *Fig. 13*), due perhaps to the difficulty in preventing the beginning of the change on *D′ E′* or to the nature of γ itself. *Fig. 11* × 33 ∨ shows the alloy slowly cooled, and consists of dark bands of Cu_3Sn or η surrounded by the lighter $SnCu_4$ or δ. The compound η separated out on reaching the temperature of the curve *D′ E*, whilst the residual solid solution γ changed over into the bright Cu_4Sn on reaching *D′ E″*.

(6) The alloys between 61·6 per cent. and 59 per cent. copper, or *E* to *F*, are very remarkable. To quote Heycock and Neville: "These go through the same stages of γ + liquid, then homogeneous γ, then $\gamma + \eta$; but when the temperature of the line *f G* is reached, the residual γ breaks up into η and liquid of the composition *G*. Thus these alloys present the somewhat rare phenomenon of the partial melt-

FIG. 21. × 120.

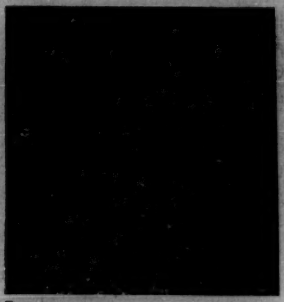

FIG. 22. × 33. V.

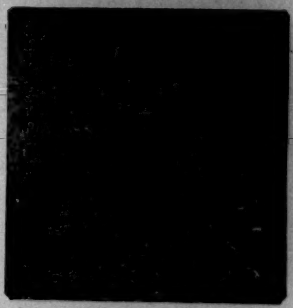

FIG. 23. × 33. V.

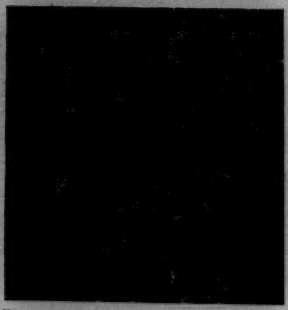

FIG. 24. × 33. V.

FIG. 25. × 33. V.

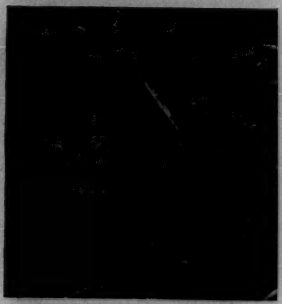

FIG. 26. × 33. V.

ing of a solid brought about by cooling it. The transformation $\gamma_f = \eta_{E'} + \text{liquid}_G$, or as we may safely write it, $\gamma_f = Cu_3Sn + \text{liquid}_G$, is the transformation which causes the angle at G in the liquidus."

(7) The alloys between 59 per cent. and 42·5 per cent. copper, or F to G, act as the above, and when cooled below the temperature E_2 G (630° C.) continue to separate out Cu_3Sn and thus enrich the liquid portion of the alloy in tin, whilst below the temperature E_3 H, or 400° C., they behave as the next series.

(8) The alloys from 42·5 per cent. to 7 per cent. copper begin to separate out the compound Cu_3Sn on reaching the liquidus G to H, and the liquid alloy is enriched in tin until it has the composition H. At this temperature E_3 H (400° C.) the compound Cu_3Sn is no longer in equilibrium with the remaining liquid, but reacts with it, and we get the compound H (approximately CuSn) formed. The reaction does not go far enough to produce complete equilibrium by changing the whole of the liquid on the left of H' and the whole of the CuSn or H on the right of H', because the crystals of the compound Cu_3Sn soon become covered by an envelope of H, which prevents further action except by diffusion. Hence a third phase is found in each case, which is enclosed by a bracket to denote it ought not to exist if the change had been complete. By keeping the alloys for several days at a temperature just below E_3 H, Heycock and Neville have succeeded in establishing equilibrium and producing two phases. As the temperature passes the line E_4 I K', the liquid, which has the composition I (about 1 per cent. copper), due to further separation of the solid H, as in the next group, solidifies as the eutectic of tin and H.

(9) Between H and I, or 7 per cent. to 1 per cent. copper, the solid H (approximately CuSn) separates out on passing the liquidus and enriches the mother-liquid in tin until, at the temperature M I, it has the composition of about 1 per cent. Cu, when it solidifies as the eutectic as before.

Lastly, the alloys containing 1 to 0 per cent. copper separate out grains and dendrites of tin on reaching the liquidus I K, whilst at the temperature I K' the remaining liquid (1 per cent. Cu) solidifies as the eutectic of tin and CuSn.

The above is a short account of the changes which occur during and after solidification in the alloys of copper and tin. The Bakerian Lecture by Heycock and Neville, "On the Constitution of the Copper-Tin Series of Alloys," is by far the best piece of work upon this subject, and is illustrated by over 100 beautiful photomicrographs which will well repay the reader.

Iron and Carbon.—The alloys of iron and carbon, due to their great importance, have been studied more than any other series. Their constitution is represented by the diagram in *Fig. 34*, which is based upon that of Professor Rooseboom.*

The freezing-point curve or liquidus is represented by *A B D*, whilst below the solidus *A a B C* everything is solid. The branch *A B* marks the commencement of solidification. Dendrites of martensite separate out and contain a maximum of about 2 per cent. carbon in solid solution. In alloys containing more than 2 per cent. carbon the martensite-graphite eutectic makes its appearance. The horizontal line *a B C* marks the evolution of heat due to its solidification. The branch *B D* corresponds to the separation of free graphite. Hence we find from 0 to 2 per cent. carbon the alloys solidify as dendrites of martensite; from 2 to 4·3 per cent. carbon or *a* to *B*, the alloys solidify as dendrites of martensite set in the groundmass or eutectic of graphite and martensite. Alloys having the composition *B* solidify as the eutectic and contain neither free martensite nor free graphite, whilst above *B* or 4·3 per cent. carbon we have free graphite (as kish) and the eutectic.

As the temperature falls from *a B C* to *E F H*, or about 1,000° C., the martensite becomes supersaturated with graphite, which separates out along the line *a E*, reducing the total carbon in solid solution to about 1·8 per cent. At the temperature *E F H* a transformation occurs. The martensite is no longer in equilibrium with graphite but reacts with it.

Martensite (1·8 per cent. C) + Graphite = Cementite (Fe_3C).

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* *Zeits. f. Phys. Chem.*, XXXIV, 1900, p. 437.

This reaction is very slow and in ordinary cooling only goes a short way, and hence we find graphite below *E F H* due to lag.

As the temperature falls below 1,000° C., the martensite becomes supersaturated with carbon, which separates out as cementite (Fe_3C) along the curve *E S* until at the temperature *S*, or just under 700° C., recalescence occurs and the residual martensite, containing about 0·8 per cent. carbon, is transformed into the eutectoid pearlite, consisting of alternate laminæ of cementite and ferrite (or pure iron).

In the case of white irons, solidification commences, as before, by the separation of dendrites of martensite, but the mother-liquid solidifies as a eutectic of martensite and cementite, on the line *E' B' F'*. This must take place because martensite and graphite are not in equilibrium, and the difference between this and gray irons is probably due to the difference in the amount of silicon, manganese and other impurities present. On further cooling the martensite is transformed in the solid as before.

Coming next to the series containing 0 to 1·8 per cent. carbon. Above the temperatures marked by the curve *G O S E* they exist as the solid solution martensite, but as the temperature falls transformations occur.

In the case of alloys containing up to *S* or 0·8 per cent. carbon, as the temperature reaches the curve *G O S* the martensite becomes supersaturated with ferrite, which separates out and enriches the martensite in carbon until it contains *S* or 0·8 per cent. at just under 700° C. At this point recalescence occurs and the residual martensite is transformed to the eutectoid pearlite. Hence within the area *G O S P* we have ferrite and martensite, whilst below *P S* we have ferrite and pearlite. The steel containing *S* or 0·8 per cent. carbon exists as martensite until the temperature *S* is reached, when it is transformed into pearlite as before. The alloys containing 0·8 to 1·8 per cent. carbon become supersaturated with cementite, which separates out along the curve *E S* and reduces the carbon in solid solution to *S* or 0·8 per cent. at just under 700° C., when the residual martensite is transformed to pearlite as before. Hence, between

FIG 27. × 120.

FIG. 28. × 120.

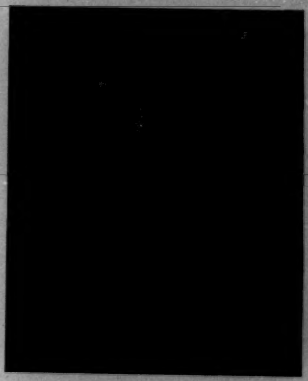

FIG. 29. × 120.

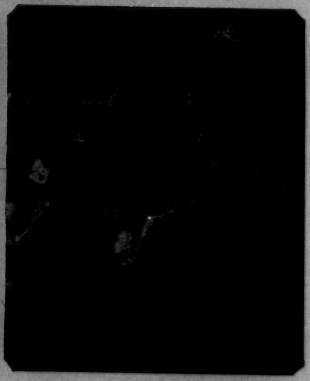

FIG. 30. × 33.

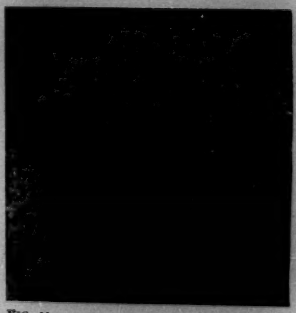

FIG. 31. × 33. V.

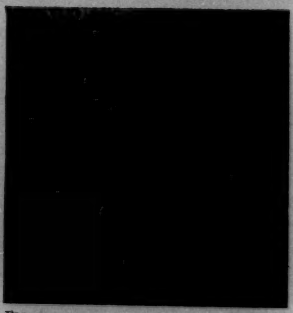

FIG. 32. × 33. V.

the temperatures $E\ S$ and $P\ S\ K$, we have cementite and martensite, whilst below the temperature $S\ K$ we have cementite and pearlite.

Another change occurs with fall of temperature. Iron has three allotropic modifications, viz., α, β and γ. The γ form exists above the temperature $G\ O\ S$, the β form within the area $G\ O\ M$, whilst the α modification occurs below $M\ O\ S$. The evolution of heat $M\ O$ is due to the transformation of β into α iron with the regain of magnetism.

These changes in the solid are of the utmost importance, because upon them depend hardening, refining and the like. Sauveur,* in a paper on "The Relation between the Structure of Steel and its Thermal and Mechanical Treatment," gives a very clear account of the changes which occur. Stead† has shown the effects of heating bars of from 0·013 to 1·14 per cent. carbon to various temperatures, whilst Arnold‡ has done much work along the same line.

The following will give some idea of the great changes which occur with heat and mechanical treatment. A steel containing 0·50 per cent. carbon and 0·98 per cent. manganese gave two critical points on heating. Ac_1 at about 700° to 710° C. very marked, and $Ac_{2,3}$ at about 745° to 750° C. very slight. On cooling, $Ar_{2,3}$ was slight at about 700° C., whilst Ar_1, the recalescence point, was very strong at 660° C. The effect of slowly heating to given temperatures and cooling in air and quenching in water was determined by physical tests and by microstructure. The material was $\frac{7}{16}$ inch square.

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* *Journal Iron and Steel Institute*, II, 1899, p. 195. (Also see *T. A. I. M. E.*, 1896.)

† *Journal Iron and Steel Institute*, I, 1898.

‡ *Jour. Iron and Steel Institute.*

The following table gives the results of physical tests:

	COOLED IN AIR.				QUENCHED IN WATER.			
Bar heated to	Elastic L., lbs. per sq. in.	Maximum Load, lbs. per sq. in.	Elongation in 8 inches.	Reduction of Area.	Elastic L., lbs. per sq. in.	Maximum Load, lbs. per sq. in.	Elongation in 8 inches.	Reduction of Area.
Degrees C.								
659	72,500	102,900	15·6	55·7	67,000	107,150	15·2	50·2
682	67,100	104,100	17·5	50·8	64,000	107,420	15·6	55·3
700	62,500	101,250	17·6	53·1	63,000	127,800	—	8·5
702	62,400	100,400	14·3	55·8	61,250	133,500	—	2·2
718	63,700	102,300	17·4	54·3	—	188,900	—	—
733	65,600	108,400	17·4	52	71,100	203,100	—	—
746	75,200	112,000	16·25	51·3	—	135,050	—	0·3
766	74,600	112,600	16·5	42·8	60,900	103,800	—	0·1
775	74,600	112,200	—	50·6	—	104,000	—	0·1
819	73,600	115,050	15	48·4	—	60,100	—	—
843	73,100	117,100	15·6	46	—	39,000	—	0·4
962	71,460	115,000	11·87	41	—	80,500	—	—
966	69,700	114,800	13·6	43·7	—	72,300	—	0·5
1030	67,600	110,300	14	38·4	—	45,750	—	—
1086	66,400	108,800	12·1	29·3	—	61,050	—	0·2
1151	66,100	109,950	8·1	34·4	—	61,300	—	—
1213	64,900	108,400	11·25	32·2	—	70,200	—	0·2
1268	66,900	112,800	8·1	13·7	—	54,900	—	—
1339	65,400	113,900	5·3	7·6	—	56,800	—	—
1390	60,700	98,200	3·4	5·4	—	61,800	—	0·6
Original	70,550	113,400	13·9	46·4				

Steel Cooled in Air.—From the above it will be seen that re-heating to the lower critical point lowers the elastic limit and maximum load uniformly, whilst from this point to the upper point $AC_{1,2}$ there is an improvement until we return to almost what we started with. The best elastic limit occurs just at this point, whilst the greatest maximum load occurs about 840° C. The elongation shows a marked improvement to a little below the upper critical point, after

which there is a regular falling off until at 1,390° C. the steel is very much overheated. The reduction of aka is greatest at Ac_1, and falls off with higher temperatures until reduced to 5½ per cent. at 1,390° C.

On examining the microstructure, the original steel, shown in *Fig. 19* × 120, consists of medium-sized grains of dark pearlite surrounded by veins of ferrite. Above 700° C. these grains are reduced in size until we get the finest structure at 733° C. or just below Ac_{2-3}. This is shown in *Fig. 27* × 120, which is the bar heated to 733° C. and slowly cooled in air. With increase in temperature, we get an increase in the size of structure. *Fig. 21* × 120 shows the bar heated 819° C., and the structure is much larger than that of the original steel. There is a better separation of the ferrite, the pearlite being less unsegregated. *Fig. 22* × 33 ∨ shows the bar heated to 966° C., whilst *Fig. 23* × 33 ∨ is the bar heated to 1,086° C. with a proportionate growth of grain. The photograph is taken at the edge of the section to show the very distinct decarburization of the outer layer. *Fig. 24* × 33 ∨ shows the steel heated to 1,151° C., and *Fig. 25* × 33 ∨ is that heated to 1,212° C., the photograph being again taken from the edge to show decarburization. The structure has become very coarse indeed. *Fig. 26* × 33 ∨ shows the steel heated to 1,339° C. The crystals have grown to an enormous size, whilst in the center of the largest a new structure is seen, which may be a relic of the old martensite which was not completely transformed on passing Ar_1. We have evidently reached the point where we get great overheating.

In considering the changes which have taken place on re-heating, we know that the *pearlite* will give the finest structure when the steel has been heated to just above Ac_1, or when it has been transformed to martensite. Heating above this point will cause a growth of structure, the higher the temperature the coarser the structure. The *ferrite* begins to diminish in size above Ac_1, because the martensite commences to dissolve it. This will continue until the whole of it has disappeared, when the change Ac_{3-2} is complete. Now, the *whole steel* will have the finest

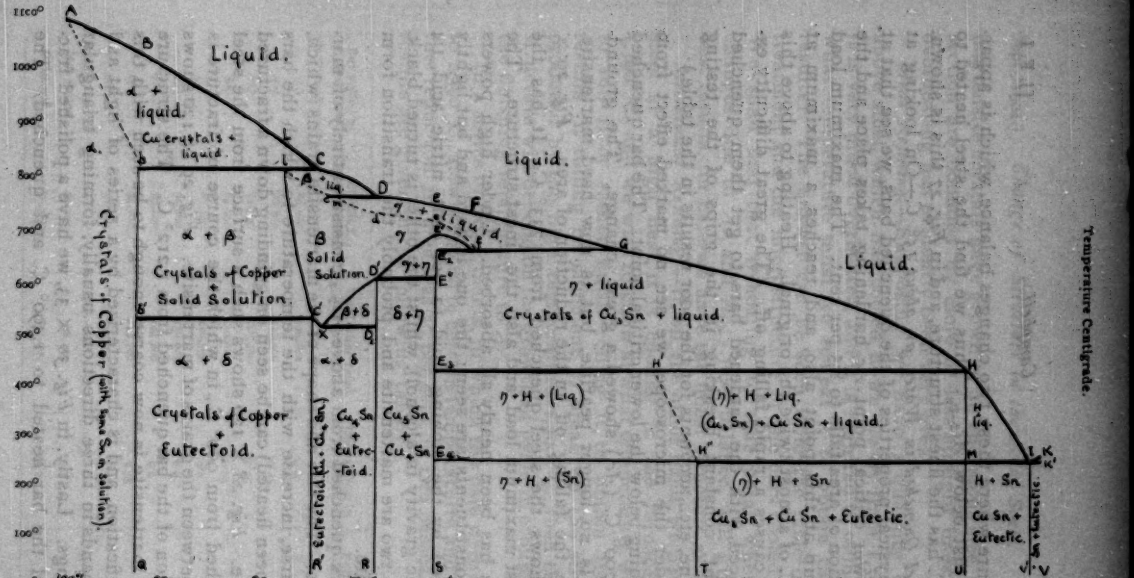


FIG. 33.—Equilibrium curve: copper-tin series.

structure where these two changes balance, which is apparently just below Ac_{2-3}. Thus we find the steel heated to 733° C. has the finest structure, and in *Fig. 27* this is shown.

Steel Quenched in Water at about 15° C.—On looking at the physical properties of the quenched bars, we see that at the lower critical point Ac_1 hardening takes place and the reduction of area falls to 8·5 per cent. The maximum load runs up at this point also, and reaches a maximum at 733° C. of almost twice the original. Heating to above this point causes a rapid falling off. (The great difficulty experienced with the hardened bars to get them quenched straight, constant breaking in the grips of the testing machine, etc., accounts for the poor results in the table.)

Under the microscope, we see no marked effect from quenching below the lower critical point. The bar quenched from 700° C. (Ac_1) showed a great change. The groundmass is no longer pearlite, but is now hard martensite. Hence the falling off in the reduction of area. *Fig. 20* × 120 shows the steel quenched from 733° C. It has the highest maximum load and also the finest structure. The ferrite has been nearly all absorbed. Under high powers two constituents are seen: the one is hard and but lightly attacked by the etching fluid (2 per cent. nitric acid, 1·4 specific gravity in alcohol), whilst the other is turned black. These two are martensite and probably the transition form tröostite.

Bars quenched from above Ac_{2-3} consist entirely of martensite. The size and shape of the martensite grains (which, of course, increase with the temperature to which the bars have been heated) can be seen on grinding down a fractured surface. *Fig. 28* × 120 shows such a surface from the steel quenched from 900° C., in which the course of fracture is seen between the grains of martensite. *Fig. 29* × 120 shows a section of the bar quenched from 1,212° C. The structure of the martensite is now coarse enough to be seen with this magnification, and is characterized by a series of light and dark bands in three directions usually, forming triangular markings. Lastly, in *Fig. 30* × 33, we have a polished fracture of the bar heated to 1,390° C. and quenched. The

martensite crystals have grown to an enormous size, and in section are bounded by more or less straight lines. The overheating has evidently been very great.

Heat Refining.—Supposing we have a quantity of the above steel, which has cooled down slowly from 1,390° C., it is very much overheated, and it is required to refine it, to what temperature must we re-heat it to obtain the best results? The answer can be seen from the table of heat treatment and the microstructure of the bars cooled in air. We shall find that re-heating to that point where the changes due to Ac_1 and Ac_{2-3} just balance, will give the best results, for here we have the finest structure as before.

Mechanical Refining.—If, on the other hand, we have our steel at a high heat, it is cooling in the furnace from 1,390° C., and we wish to know at what temperature we have to roll it, or rather finish rolling it, to obtain the best results; if rolling be sufficient to break up the structure produced by the high temperature 1,390° C., then the final structure will depend on the growth of grain in cooling from the finishing temperature to Ar_1.

In a series of experiments, in which the bars were heated to 1,390° C., slowly cooled to certain temperatures and rolled, the reduction in area was 30 per cent. in two passes. The results are given in the following table:

Bar rolled at — Degrees C.	Elastic L., lbs. per. sq. in.	Maximum Load, lbs. per sq. in.	Elongation in 8 inches.	Reduction of Area.
963	86,050	126,800	9·6	28·0
909	85,800	127,300	10·25	27·0
837	84,400	126,400	10·25	29·3
809	84,700	126,000	10·75	33·1
781	87,700	126,500	10·0	33·3
782	93,100	130,000	8·0	39·0
734	89,400	124,200	9·4	41·3
695	94,700	129,100	9·75	39·6
667	98,050	130,300	8·75	27·3
Not rolled.	60,700	98,200	3·4	5·4
Original.	70,550	113,400	13·9	46·4

On examining the results of physical tests it is seen that the elastic limit shows a great increase throughout. The maximum load has also passed that of the original and is greatest at the lowest rolling temperature. The elongation has been raised from 3·4 per cent. in the bars cooled in air from 1,390° C. to an average of 9·5 per cent., and is very fair when compared with that of the original steel, viz., 13·9 per cent. The reduction of area shows the more marked varia-

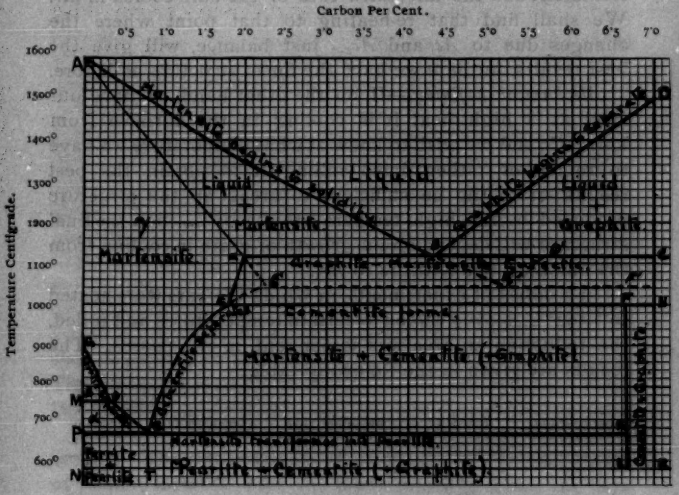


FIG. 34.—Equilibrium curve: iron carbon series.

tion. The bars heated to 1,390° and rolled at 752° and 724° C., respectively, show the best reduction—39 and 41·3 per cent. This is good, when compared with the unrolled bars and with the original with 5·4 and 46·4 per cent., respectively.

On examining the microstructure we find that the lower the rolling temperature the finer the grain, down to the bar rolled at 724° C., below which there is apparently a slight increase in size. In each case there has been more or less decarburization of the outside layer. In the bar rolled at

the highest temperature we have the largest grain, but this is very small when compared with that of the overheated bar. The ferrite has separated out as thin veins round the grains of pearlite, and also in them as irregular patches. With the lowering of the rolling temperature, we find little difference in the ferrite except that the veins are smaller because they follow the grain, and there is less free ferrite within the grain itself. On reaching the bar rolled at 724° C., a marked change is noticed. The ferrite veins round the outside of the specimen begin to thicken very much. This is seen in *Fig. 31* × 33 ∨, which shows the corner of this bar. The decarburized layer is seen on the top and left, whilst just within this zone a thickening of the ferrite is seen. This shows that the outer layer had reached the upper critical temperature before work had ceased. This is the steel which has been most refined. Below this we find that the thickening of the ferrite veins occurs right through the steel, or rolling was finished whilst the whole was below Ar_{2-3}. The bar rolled at 667° C., the lowest temperature, is shown in *Fig. 32* × 33 ∨. The coarsening of the ferrite walls is seen throughout the section. The top is near the edge and we have decarburization as before, but here we probably have the traces of cold rolling, for under high powers the ferrite has separated out as flattened forms and the pearlite is often abnormally coarse.

Although no rule can be drawn from one series of experiments, it is evident that, with the methods used, the best finishing temperature is such that the bars leave the rolls as near Ar_{2-3} as possible. The bars would of course have to be drawn from the furnace at a slightly higher temperature, to allow for cooling in the rolls. Making an allowance of say 40°, the rolling temperature would be about 740° C. This agrees with the experimental results shown in the table, for the two bars rolled at 752° and 724° C., respectively, gave the best results. The reason why the bar rolled at 667° C. does not show more traces of cold-rolling is because of the great evolution of heat at the recalescence point.

From the above examples are seen the great changes which occur, not only in iron and steel, but also in other

alloys, and cause a more or less complete rearrangement of structure. As the physical properties vary with the structure, great stress must be laid upon these changes in the solid, and our study of the effects of heat treatment must accompany that of microstructure, because the two go hand-in-hand and help to interpret each other.

THE EMPTY CAR HAUL.

The bane of railroad operation is the empty car haul, and to its reduction the best efforts of the transportation department are being constantly put forth. It is realized that the movement cost of each ton is the same whether it is embodied in the car itself or in its contents, and when it is considered that from 30 to 40 per cent. of the total tonnage moved by railroads consists of empty car haul, the importance of the question is easily understood. In view, therefore, of the magnitude of the subject and the part that it plays in operating expenses, it seems a little strange that a car of general utility, that is to say, one which could be used for two or more special commodities, has not yet been evolved. A number of attempts have been made to provide a car which would answer for both live stock and merchandise, but that appears to be impossible in the nature of things. A car suitable for joint use in coal and live stock traffic, or in coal and merchandise traffic, would seem to be more nearly possible, and we understand efforts are now being made in both of these directions. There is certainly enough to be gained by the production of a successful car of this character to warrant the devotion of the time and energy for its production.—*Railway Age.*

PHOTOLINOL.

Some interesting demonstrations have been carried out in London with a new photographic art material called "photolinol." This fabric is composed of linen, which is thoroughly permeated with the photograph, producing a high translucency. One very picturesque effect obtained by this means is that the picture, when colored and viewed with a reflected light, bears a very strong resemblance to an oil-painting, the lines of the weaving of the linen appearing similar to the canvas in a painting. Photolinol is waterproof and indestructible, while the photograph does not fade in the sun, as it appears to be woven into the material. By its aid much greater enlargements than are now possible can be made with ease. The fabric can be made to any size, some of the enlargements shown being 10 feet square. It is applicable to an extensive variety of purposes. As it is transparent, it can be adapted to lamp shades and other ramifications of photographic art for which transparencies are now employed. Novel results can be obtained with it, for the picture appears with equal distinctness on either side by either reflected or transmitted light. The process is a secret one, but its commercial utility and value are already asserted, since it can be employed for curtains, screens or theatrical scenery. For the latter it is peculiarly adapted, and is both cheaper and more durable than hand-painted scenery.—*Scientific American.*

ELECTRICAL SECTION.

Stated Meeting, held Thursday, March 3, 1904.

Circuit-Breakers.

By W. M. Scott.

The topic which has been assigned for this evening's discussion is one of such breadth that I will confine my discussion to but a single type of circuit-breaking apparatus, the "Reverse Current" Circuit Breaker, and will dwell more particularly on the form of this device which has been developed by the company with which I am associated, and who have for some years past been closely identified with the development of the "Reverse Current" circuit breaker.

A "Reverse Current" circuit breaker, or, as it is sometimes very aptly called, a "Discriminating Cut-out," is a circuit breaker which automatically severs the circuit in the event of the flow of current being abnormal in direction, and which, unless interrupted, would result in misapplication of energy. The "Reverse Current" circuit breaker most perfectly adapted to the requirements of engineering practice is one which is dependent for its operation solely upon the occurrence of reverse current flow. It is desirable also that loss of voltage shall not cause the opening of the "Reverse Current" circuit breaker, and it should be so constructed that it can be closed upon open circuit. In order to meet the varying conditions which may arise in the use of the circuit breaker, the volume of reverse current necessary for its actuation should be subject to convenient adjustment. The operation of the circuit breaker should be independent of voltage variations throughout the normal working range, and should be positive at all voltages to which it is liable. The force tending to cause the opening of the circuit breaker upon reversal should increase with the volume of the reverse current. In these last respects, particularly, many of the reverse current devices on the market are conspicuously defective. Considering, as an instance,

those which depend for their opening force upon a tripping coil which, when brought into circuit by means of a polarized relay actuated by a reversal of the current, is energized by the voltage of the system, it will be seen that where the reversal reaches the magnitude of a short-circuit, the voltage of the system may be reduced to but a fraction of its normal value, and the tripping coil may, as a result, be insufficiently energized to effect the opening of the circuit breaker.

Where, in order to avoid this very evident cause of failure, the tripping coil is connected in an independent circuit, new complications are introduced without corresponding advantage.

Obviously the operation of any safety device should depend entirely upon the conditions prevailing in the circuit to be protected, and its effectiveness should not be determined or limited by the condition of some independent circuit or appliance, the failure or disconnection of which may render the safety device inoperative at the critical moment. The following is a description of the I-T-E "Reversite" circuit breaker, upon the perfecting of which we have been at work for a number of years. In its operation all of the foregoing requirements are fully met.

Referring to the accompanying illustration (Plate I), it will be seen that the reversal feature of this circuit breaker is secured by the co-operation of two electro-magnetic systems: one consisting of a pivoted core and pole pieces depending for excitation upon a coil connected in the main circuit; the second of two independent cores, parallel with the first and excited in sympathy with each other by two magnetizing coils which are subject to the full voltage of the circuit. The pole pieces of the series magnet normally stand just midway between the polar extensions of the cores of the shunt-wound system. In this position they are supported from below by suitable stops. They are free, however, to move upward into engagement with the upper core, and in so doing cause the release of the latch restraining the switch. The windings and connections of the exciting coils of these two systems are so related that

during the flow of current in the direct sense the movable pole pieces are held in their medial position by the attraction of the lower core acting in addition to the effect of gravity, while upon a reverse current flow the pole pieces are drawn upward in opposition to gravitation into engagement with the upper core, these opposite reactions being due to the fact that the magnetism induced by the

PLATE I.—I-T-E "Reversite" circuit breaker, with overload actuation.

shunt coils is not subject to change in direction upon a reversal in the main circuit. Upon direct current flow, therefore, the series magnetism compounds with that of the lower shunt magnet, while upon reverse flow it compounds with that of the upper one. It will thus be seen that the operation of the

circuit breaker is dependent upon the co-operation of voltage and current. Although on account of the location of the movable pole pieces midway between the shunt-excited cores, the voltage alone will not cause the operation of the circuit breaker; nevertheless, at and considerably below normal voltage, the shunt excitation provides quite sufficient power for this purpose, when made effective by placing the movable pole pieces above their neutral position; but upon reversal the magnetism due to the flow of reverse current supplements that of the shunt-excited core toward which the movable pole pieces are attracted. The effect of this in insuring positiveness in the operation of the circuit breaker may be best understood by an inspection of the accompanying diagram (Plate II), illustrating the performance of a 600-ampere "Reversite" circuit breaker, designed for the protection of a 500-volt generator operating in multiple with others similarly protected.

The ordinates of these curves correspond with the various voltages upon which the circuit breaker was tested, the abscissæ with the corresponding reverse currents required for the operation of the circuit breaker and consequent opening of the circuit. The three curves coincide respectively with 8, 20, and 75 amperes adjustment, which are correct at 500 volts pressure. It will be noticed that for variations of 100 volts either way from normal the performance of the instrument corresponds closely with the calibrations, that as the voltage of the circuit falls the value of reverse current necessary for the operation of the instrument continues to increase; but within the limits of the test, which was carried down to 30 volts, the operation of the instrument was uniformly reliable and positive. When at any voltage the reverse current had reached such a value as to cause the initial motion of the movable magnetic system away from its neutral position, there was ample energy supplied for the tripping of the circuit breaker. An inspection of the curves shows that they are of the nature of rectilinear hyperbolas, the asymtotes corresponding respectively with a vertical line drawn through the zero value of the current, and with a horizontal line somewhat below the zero volt-

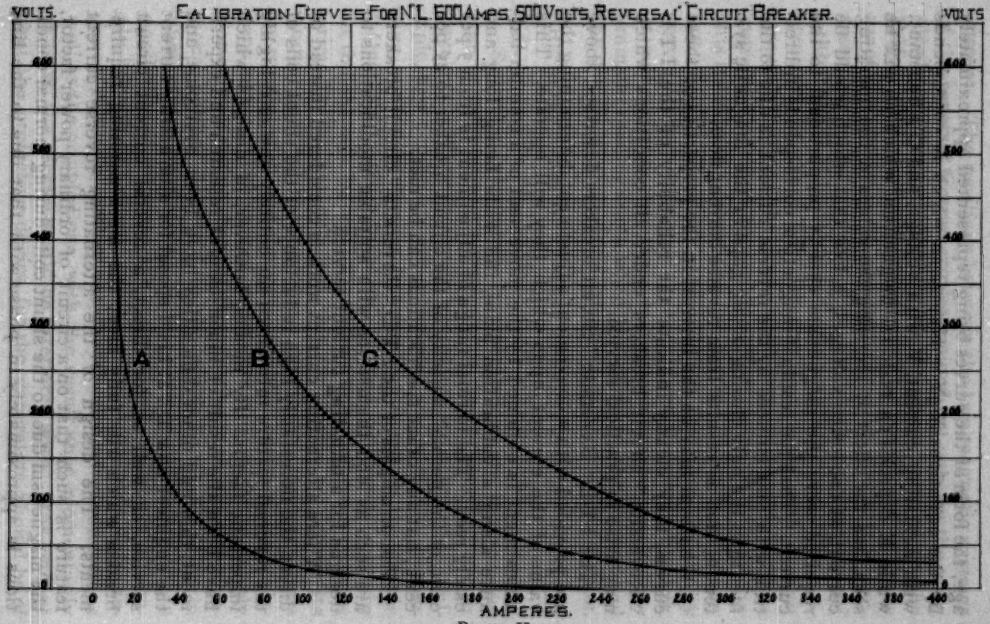

VOLTS.
CALIBRATION CURVES FOR N°L. 600 AMPS., 500 VOLTS, REVERSAL CIRCUIT BREAKER.
VOLTS
600
500
400
300
200
100
0
A
B
C
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
AMPERES.

PLATE II.

age, the form of the curves bring represented approximately by the equations $X(Y + K) = C$, in which X corresponds with actuating current, Y with voltage, and C a constant, while K depends on residual magnetism, which, as will be seen, has the effect of reducing the values of the operating current, at the lower voltages, below that which would be required were the magnetism exactly proportional to the current. That the residual magnetism corresponds in direction with that induced by the reverse current is due to the fact that the only closing of air gaps in the magnetic system is such as results from reverse current flow.

Whatever may be the interest in the properties of these curves, they clearly indicate the reliability of the I-T-E "Reversite" circuit breakers under all conditions which may arise in practical service.

The I-T-E "Reversite" circuit breakers described above are provided with a convenient adjustment determining the value of the current upon which they will operate. This adjustment is obtained by the movement of a counter-balance along a calibration plate, the scale being long and easily read. The normal range of adjustment is from 5 per cent. of the normal capacity of the circuit breaker to 25 per cent., but any other specifications can be met.

The principles of the I-T-E "Reversite" circuit breakers are such as lend themselves with suitable modifications to designs for alternating current service.

Where alternating current work is considered instead of direct, the necessarily high inductance of the shunt coils of the reversal feature introduces an entirely new and highly important factor. By means, however, of designs which have been the result of much careful research and experiment, this and other difficulties have been overcome, and the engineer now has at his disposal for alternating current service, as well as for direct, a reverse current circuit breaker which will fully meet the most exacting requirements. The design of the alternating reverse current feature is such that on a circuit of ordinary power factor, the magnetism due to the shunt coils during normal conditions is approximately in phase with that due to the line

current. The reactions between the two magnetic systems of the reversal feature are determined not only by the magnitude of the current, but by its phase relation to the E.M.F. The reverse current may be considered as made up of two components; one in phase with the E.M.F., representing reverse energy flow, and a second lagging 90° behind the E.M.F., representing a wattless flow. The construction of the I-T-E reversal feature is such that it responds only to the first-named component, the wattless currents having no appreciable effect on its operation. For this reason the calibrations are marked in units of power, not in units of current, and indicate, therefore, the energy reversal which will cause the opening of the circuit breaker. It will be seen that these indications can be checked by ammeter readings only when the phase of the current and the voltage of the system are also taken into consideration.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF GENERATORS.

So long as generators are operated singly, their protection is fully insured by the use of simple overload circuit breakers. When, however, generators are operated in multiple, new conditions are introduced which require protective appliances having features not found in the simple "Overload" circuit breakers. Where generators are run in this manner, in case of accident to one of them or to its prime mover, not only will this unit cease to deliver its quota of current to the external circuit, but the other units in parallel with the damaged one will begin to force current into it. The normal generators will, therefore, supply not only an undue share of the effective load, but also additional current delivered to the crippled unit, resulting in unnecessary overloading of the normal generators and a possibility of injury to the crippled one. The use of simple "Overload" circuit breakers would, in such a contingency, result in cutting out the disaffected generators as well as the crippled one, with the result that, momentarily at least, the service would be interfered with. It is evident that the protective device for the generators should be of

such a character that the crippled unit shall be automatically disconnected before it shall have taxed the others. Thus the load will at once devolve upon the normal units without even a momentary interruption of the current supply. The only protective device which adequately meets these requirements is the I-T-E "Reversite" circuit breaker. Where each generator of the system is thus protected, crippled units will be immediately disconnected.

The protection afforded by "Reversite" circuit breakers is of especial value in power plants, the demands upon which are such that reserve units must frequently be thrown into service. Such a requirement is often of the nature of an emergency, and it is of the utmost importance, therefore, that the necessary connections shall be made promptly. If, however, the engineer connects the reserve unit to the bus bars an instant too soon, in the absence of proper protective devices, the current reverses into it and it thus adds to the load upon the other generators. Where each generator is protected with an I-T-E "Reversite" circuit breaker, no unit can be effectively thrown into parallel with the others until it is up to the voltage. The use of this type of circuit breaker gives the engineer confidence, saves delay and affords the generator complete protection.

"Reversite" circuit breakers also have an incidental value, in that they serve to automatically disconnect each generator, as its prime mover is slowed down when the generator is being taken out of service, as the instant the slowing down results in a drop in voltage of the generator, a reversal takes place which opens the circuit breaker.

The method of connecting "Reversite" circuit breakers for the protection of generators operating in multiple is shown in the accompanying cut, Plate III. The two poles of the circuit breaker are introduced in the usual manner into the circuits of the generator leads; the shunt coil is then connected so as to receive full line pressure. One terminal of the coil is to be attached to the small spring contact located back of the left-hand switch member of the circuit breaker; the other terminal must connect with the

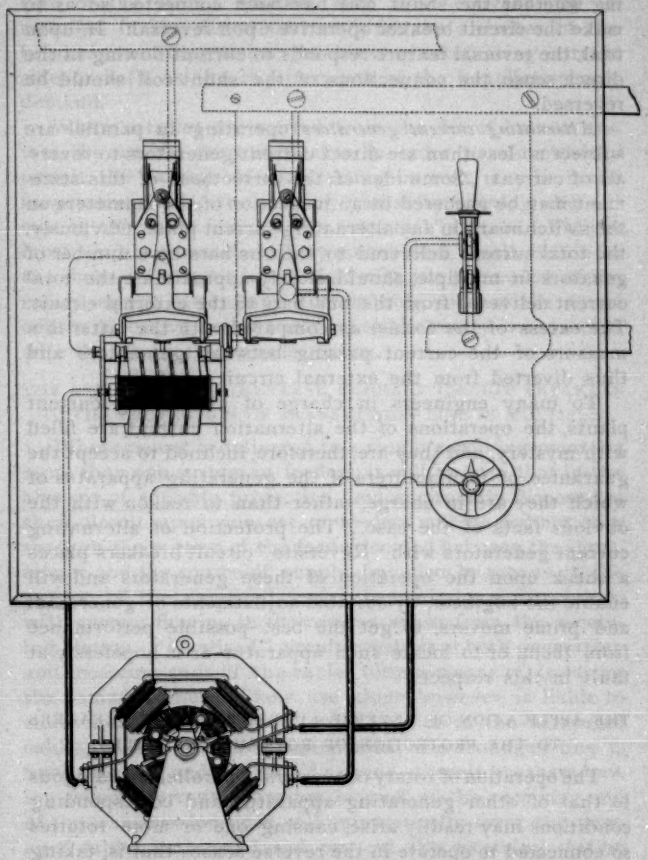


PLATE III.

bus bar of opposite polarity. The actual passage of current from the generator is perhaps the best method of ascertaining whether the shunt coil has been connected so as to make the circuit breaker operative upon reversal. If, upon trial, the reversal feature responds to current flowing in the direct sense, the connections of the shunt coil should be reversed.

Alternating current generators operating in parallel are subject no less than are direct current generators to reversals of current. Some idea of the correctness of this statement may be gathered by an inspection of the ammeters on the switchboard in any alternating current plan. Obviously, the total current delivered to the bus bars by a number of genators in multiple, should closely approximate the total current delivered from the bus bars to the external circuit. The excess of the former as compared with the latter is a measure of the current passing between generators and thus diverted from the external circuit.

To many engineers in charge of alternating current plants, the operations of the alternation current are filled with mystery, and they are, therefore, inclined to accept the guarantee of manfacturers of the generating apparatus of which they are in charge, rather than to reckon with the obvious facts of the case. The protection of alternating current generators with "Reversite" circuit breakers places a check upon the operation of these generators and will enable the engineer, by suitable adjustments of generators and prime movers, to get the best possible performance from them, or to locate such apparatus as is hopelessly at fault in this respect.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF ROTARY CONVERTERS.

The operation of rotary converters in parallel is analogous to that of other generating apparatus, and corresponding conditions may readily arise, causing one or more rotaries so connected to operate in the reverse sense; that is, taking current from the direct current side and delivering power to the alternating current mains. Where the rotaries are

protected by "Reversite" circuit breakers, such tendencies are arrested in their incipient stages. The "reversal" feature of the circuit breaker may most conveniently be installed in the direct current side, the switches of the breaker controlling either the direct or alternating current side, or both, as the requirements of the installation may demand.

Where rotaries are started from the direct current system, the reverse current breaker, in order to conveniently permit the passage of the starting current, may be made inoperative during the starting period by opening the circuit of the shunt coils of the "reversal" feature. This is most readily accomplished by means of a small switch in the shunt coil circuit interlocked with the line switch of the rotary on the alternating current side, so that the shunt coils will receive current only when the rotary is connected with the alternating current mains.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF TRANSMISSION LINE IN MULTIPLE.

Where power is delivered to a single receiving point by more than one system of feeders, it will be seen that in the absence of suitable protective devices properly disposed, a short-circuit upon one set of feeders will be fed not only through the portion of the feeder located between the short-circuit and the source of supply, but also by means of the portion of the damaged feeder beyond the short circuit, with current flowing in the reverse sense from the receiving station. "Overload" circuit breakers at both generating and receiving ends of the cables form a means of isolating the damaged lines. Their use alone, however, is liable to cause momentary interruption of service in the uninjured cables, which will be repeated until the damaged line is finally located and put out of service. Circuit breakers having reverse current operation located at the receiving end of the transmission lines will automatically sever the damaged cables at this end and prevent the receiving station from feeding back into the short circuit; this being attained without even momentary interruption of the service. These

considerations have equal importance in both direct current and alternating current practice, with perhaps a wider scope of application in the latter field. In combination with "overload" circuit breakers at the generating end of the feeders, "Reversite" circuit breakers at the receiving end should give adequate protection under all conditions of service which are likely to arise.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF STORAGE BATTERIES AND SYSTEMS OF WHICH STORAGE BATTERIES FORM A PART.

The wide application of storage batteries in connection with electrical installations of various types renders desirable a knowledge of the forms of protective apparatus best suited to the requirements of this class of service. The manner in which the storage battery is handled plays a very important part, both in determining the length of its life and its efficiency. Where batteries are charged at too high a rate, the plates are subject to sulphating and other forms of injury, from which the battery is slow to recover. Discharge of the battery under abnormal conditions is also likely to cause serious damage. Where storage batteries are constantly under the eye of skilled attendants, guided by suitable indicating instruments, these dangers are perhaps somewhat reduced. They may in all cases be minimized and in most cases entirely eliminated by the installation of suitable protective devices.

Considering first the protection of automobile storage batteries, these are quite frequently charged from a generating plant devoted exclusively to this purpose. Among the contingencies likely to arise, are: connecting the battery into circuit incorrectly, so that its electro-motive force shall be cumulative with that of the generators, thus subjecting the batteries to an abnormally high discharge rate; or, where the battery is properly connected, it may be subjected to a charging current in excess of its safe limit. Disastrous results from such causes may be entirely prevented by the use of "overload" circuit breakers.

During the period of charging, should the charging

generator lose its field, or for any other reason drop its voltage, the storage battery will tend to reverse into it and operate it as a motor, and this without such indication of abnormal conditions as would attract the eye of the attendant. The battery would thus, to all appearances, be charging, while in point of fact it would be undergoing discharge, resulting not only in undue waste of energy, but wear and tear on the battery and loss of time as well. A somewhat similar condition is likely to arise where the battery is charged from a generator engaged in supplying current to an external circuit. Under these conditions, the causes of reversal of the battery into the generator would be the same as those already cited, and in addition thereto, should the generator for any reason be cut out of service, the battery would take up the load on the external circuit, and thus again the attendant might readily be misled as to the real condition of affairs. Particularly would this be the case if the generator were remote from that point in the circuit to which the storage battery was connected. A "Reversite" circuit breaker in the circuit of the storage battery would serve automatically to disconnect the battery coincident with the first flow of current from it into the external circuit.

Sometimes in automobile charging stations, a number of batteries may be left in connection with the same charging mains at a time when the generators are disconnected. Where this occurs, the stronger or more highly charged batteries will discharge themselves into those more nearly exhausted, and should any one of the batteries be short-circuited, this would result in injury to all of the others. This contingency also may be guarded against by the installation of a "Reversite" circuit breaker in each battery-charging circuit as shown in Plate IV, which represents a panel such as may be employed in charging a battery from a constant potential circuit, the current being regulated by the line rheostat shown in the lower section of the panel.

Very frequently batteries, particularly those of automobiles, are charged from a motor generator especially installed for that purpose. In such instances, most fre-

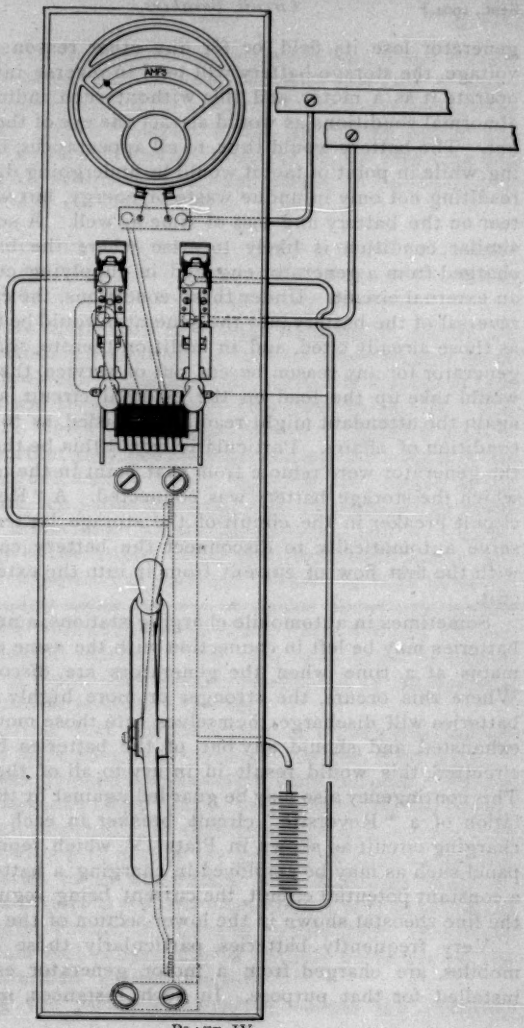


PLATE IV.

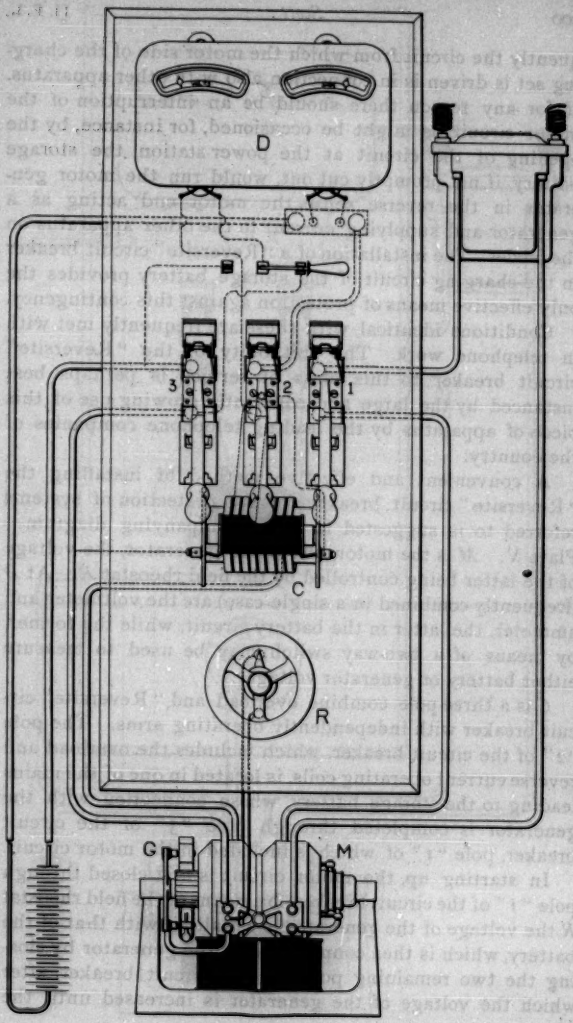


PLATE V.

quently the circuit from which the motor side of the charging set is driven is in connection also with other apparatus. If for any reason there should be an interruption of the motor circuit, as might be occasioned, for instance, by the opening of the circuit at the power-station, the storage battery, if not promptly cut out, would run the motor generator in the reverse sense, the motor end acting as a generator and supplying current to the other apparatus on the feeder. The installation of a "Reversite" circuit breaker in the charging circuit of the storage battery provides the only effective means of protection against this contingency.

Conditions identical with these are frequently met with in telephone work. The suitability of the "Reversite" circuit breaker to this class of service is perhaps best instanced by the large and constantly growing use of this piece of apparatus by the leading telephone companies of the country.

A convenient and effective method of installing the "Reversite" circuit breaker for the protection of systems referred to is suggested in the accompanying diagram—Plate V. *M* is the motor, and *G* the generator, the voltage of the latter being controlled by the field rheostat *R*. At *D* (frequently combined in a single case) are the voltmeter and ammeter, the latter in the battery circuit, while the former, by means of a two-way switch, may be used to measure either battery or generator voltage.

C is a three-pole combine overload and "Reversite" circuit breaker with independently operating arms. The pole "2" of the circuit breaker, which includes the overload and reverse current operating coils, is located in one of the mains leading to the storage battery, whose connection with the generator is completed through pole "3" of the circuit breaker, pole "1" of which is included in the motor circuit.

In starting up, the motor circuit is first closed through pole "1" of the circuit breaker; by means of the field rheostat *R* the voltage of the generator is equalized with that of the battery, which is then connected with the generator by closing the two remaining poles of the circuit breaker, after which the voltage of the generator is increased until the

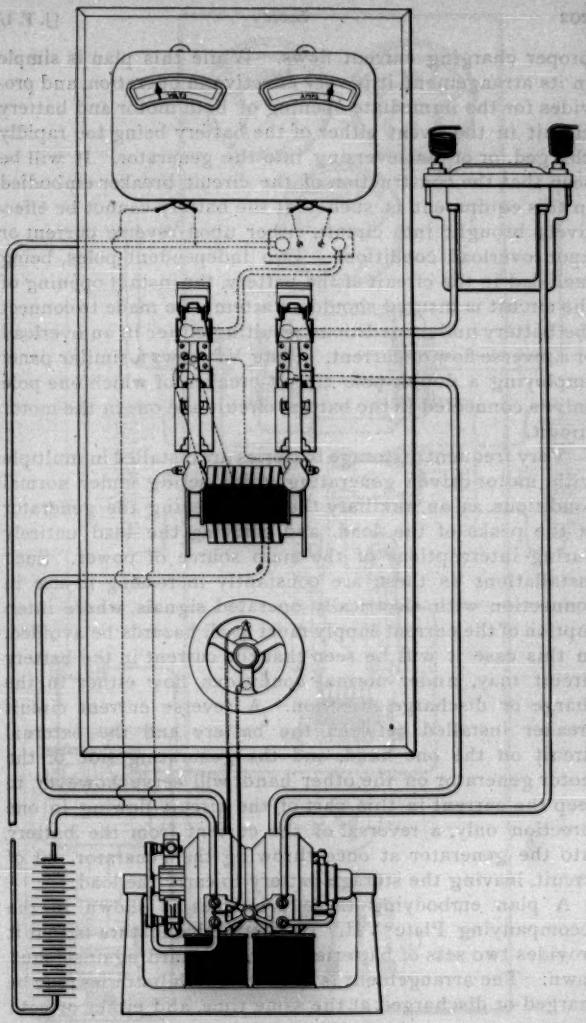


PLATE VI.

proper charging current flows. While this plan is simple in its arrangement, it is very effective in operation, and provides for the immediate opening of both motor and battery circuit in the event either of the battery being too rapidly charged, or of its reversing into the generator. It will be seen that the construction of the circuit breaker embodied in this equipment is such that the battery cannot be effectively brought into circuit, either upon reverse current or upon overload conditions. Two independent poles being included in the circuit of the battery, the instant opening of the circuit is insured should an attempt be made to connect the battery under conditions resulting either in an overload or a reverse flow of current. Plate VI shows a similar panel employing a double-pole circuit breaker, of which one pole only is connected in the battery circuit and one in the motor circuit.

Very frequently storage batteries are installed in multiple with motor-driven generating units, acting under normal conditions as an auxiliary thereto, relieving the generator of the peaks of the load, and carrying the load entirely during interruptions of the main source of power. Such installations as these are constantly increasing in use in connection with electrically operated signals, where interruption of the current supply must at all hazards be avoided. In this case it will be seen that the current in the battery circuit may, under normal conditions, flow either in the charge or discharge direction. A reverse current circuit breaker installed between the battery and the external circuit on the one hand, and the generating side of the motor generator on the other hand, will serve, however, to keep the current in this part of the circuit flowing in one direction only, a reversal of the current from the battery into the generator at once throwing the generator out of circuit, leaving the storage battery to carry the load.

A plan embodying these principles is shown in the accompanying Plate VII. Its distinctive feature is that it provides two sets of batteries as a safeguard against shutdown. The arrangement is such that both batteries may be charged or discharged at the same time, and either or both

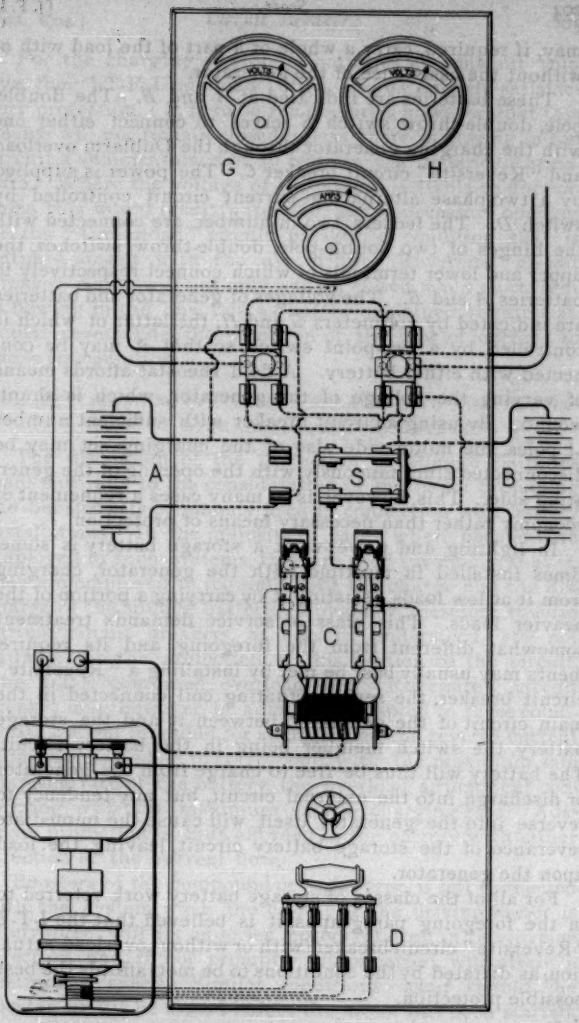


PLATE VII.

may, if required, carry a whole or a part of the load with or without the assistance of the generator.

These batteries are indicated at *A* and *B*. The double-pole, double-throw switch *S* serves to connect either one with the charging generator through the Dublarm overload and "Reversite" circuit breaker *C*. The power is supplied by a two-phase alternating current circuit controlled by switch *D*. The feeders, two in number, are connected with the hinges of two double-pole, double-throw switches, the upper and lower terminals of which connect respectively to batteries *A* and *B*. The voltages of generator and batteries are indicated by voltmeters *G* and *H*, the latter of which is controlled by a two-point switch, so that it may be connected with either battery. A field rheostat affords means of varying the voltage of the generator, which is shunt-wound. By using a circuit breaker with sufficient number of poles, the motor side also of the charging set may be disconnected simultaneously with the opening of the generating side. This, however, is in many cases a refinement of economy rather than necessary means of protection.

In lighting and power-work a storage battery is sometimes installed in multiple with the generator, charging from it at low loads, assisting it by carrying a portion of the heavier loads. This class of service demands treatment somewhat different from the foregoing, and its requirements may usually best be met by installing a "Reversite" circuit breaker, the series actuating coil connected in the main circuit of the generator, between it and the storage battery, the switch member being in the battery circuit. The battery will thus be free to charge from the generator or discharge into the external circuit, but any tendency to reverse into the generator itself will cause the immediate severance of the storage battery circuit, leaving the load upon the generator.

For all of the classes of storage battery work referred to in the foregoing paragraphs, it is believed that the I-T-E "Reversite" circuit breaker (with or without overload actuation, as dictated by the conditions to be met) affords the best possible protection.

For the charging of storage batteries at constant voltage, the "I-T-E Underload" often affords entirely satisfactory protection. It is to be remembered, however, that this device will not remain closed unless there is flowing in the circuit a sufficient current to restrain the underload armature. Where the voltage of the circuit is liable to fluctuations, this would result in frequent and unnecessary opening of the "Underload" circuit breaker, a condition that is entirely absent with the use of the "Reversite" circuit breaker, which will not only remain closed when no current is flowing in the line, but, as before explained, requires an actual reversal in the direction of the flow of current to cause its operation.

THE APPLICATION OF CIRCUIT BREAKERS TO THE PROTECTION OF STORAGE BATTERY BOOSTERS.

The discussion of the protection of storage batteries leads naturally to the consideration of means for protecting the booster sets commonly used in connection with battery installations. In the majority of cases, where boosters are employed in such systems, they are used reversibly, that is, they are employed to regulate both the charge and the discharge of the storage battery. Obviously, therefore, reverse current circuit breakers, as usually understood, are not suitable for the protection of this portion of the circuit. The I-T-E combined overload and "Reversite" circuit breaker may, however, be admirably adapted to these conditions. When intended for such service, the reverse current adjustment is made to correspond with the maximum safe charging rate of the battery, the overload adjustment conforming with the maximum safe discharging rate. Adequate protection is thus afforded to the battery with either direction of the current flow.

Boosters of the compound or series type, if left connected with the system when the circuit of the driving motor is interrupted, will act as series motors rotating in the reverse direction, and, if not promptly disconnected, will attain a destructive speed. Similar conditions occur should the booster circuit be closed before the motor has been started,

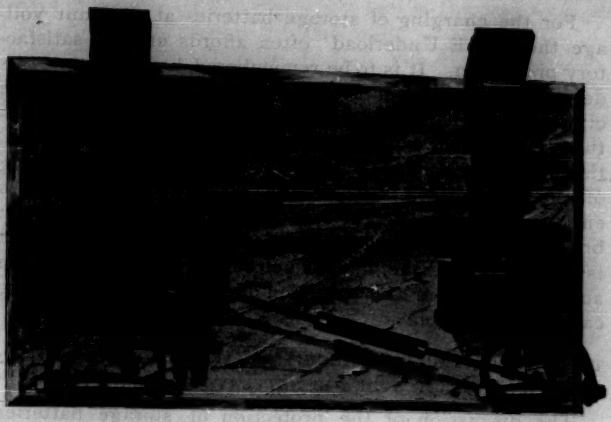


PLATE VIII.

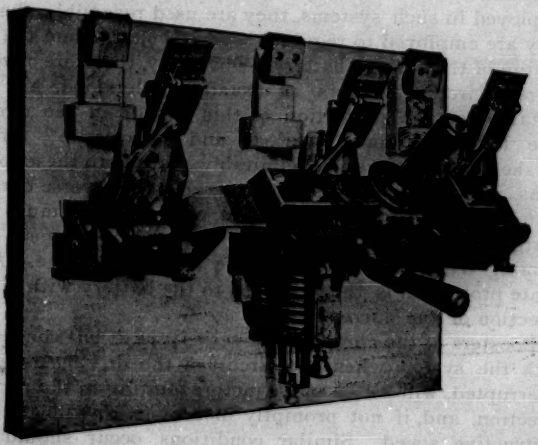


PLATE IX.

or should the motor for any reason lose its field. Proper protection under these conditions is secured only by having an overload and no-voltage circuit breaker in the motor circuit inter-connected with the circuit breaker in the battery circuit in such a manner that the motor circuit breaker must be closed before the booster circuit breaker can be made to latch, while the opening of the first-named instrument instantly causes the opening of the second.

The inter-connection of the circuit breakers may be either electrical or mechanical. Where the electrical method is employed, the booster breaker is provided with an auxiliary tripping coil brought into circuit by means of a contact device operated by the opening of the motor circuit breaker. In the mechanical arrangement, a lever suitably connecting motor and booster breakers is actuated upon the opening of the former, to release the latch of the latter. This method of inter-connection is illustrated in the accompanying cut, Plate VIII.

THE APPLICATION OF CIRCUIT BREAKERS TO THE PROTECTION OF BOOSTERS SUPPLYING FEEDERS.

Boosters employed to compensate voltage losses in feeders, incident upon transmission over considerable distances, are either series or compound wound; if, therefore, when for any reason the driving motor is not receiving current, the booster should be left in connection with the system, it will run reversely as a motor, and in view of its series field winding will attain destructive speed. This condition may be adequately dealt with by the employment of inter-connected circuit breakers as described in the foregoing section, the motor circuit breaker being of the overload and "no-voltage" type, while the circuit breaker in the booster circuit will, as a rule, need no other actuation than that transmitted from the motor breaker by the inter-connecting device.

Plate IX shows a type of circuit breaker which has been very successfully employed in connection with booster sets having a generator on each side of the line. The outer switches serve to connect the two boosters to the positive

and negative sides of the line respectively; the center circuit breaker operating upon either overload or "no-voltage" serves also to cause the opening of the booster switches.

THE PENETRATING POWER OF "N_1-RAYS."

Professor Blondlot recently drew attention to a novel kind of N-rays, diminishing, instead of augmenting, the phosphorescence of calcium sulphide. These rays, called by him "N_1-rays," are given off from a Nernst lamp simultaneously with the N-rays, and are also produced by stretching out a copper, silver or platinum wire.

In a memoir recently presented to the French Academy of Sciences, Mr. Julien Meyer describes some experiments with these N_1-rays, produced by an extended glass or copper wire or else by a closed glass tube in the interior of which the pressure is diminished. The glass of the tube, on account of the strain resulting from the difference in pressure, was in fact found to be a powerful source of N_1-rays. The brilliancy of a screen covered with sulphide spots and introduced into a glass bulb resting on the plate of an air pump would diminish when the machine was started, but would recover its initial value as the air was allowed to re-enter. If the sulphide screen be placed outside of the bulb, the phosphorescence would likewise diminish from the very first stroke of the piston. An incandescent lamp bulb, not traversed by any current, a hydrogen Geissler tube, a Crookes' tube, were all found to be sources of N_1-rays without being actuated by a Ruhmkorff coil.

While the N_1-rays from a Nernst lamp are arrested by an oxidized lead plate or by a sheet of moistened paper, those issuing from the sources named are gifted with a high penetrating power; in fact, the action of incandescent lamp bulbs on the screen is not appreciably diminished if between the bulb and the screen there be inserted a board 10 centimeters in thickness or a sheet of oxidized lead 1 millimeter in thickness and folded around itself so as to be traversed eight times, or else a glass vessel filled with pure water. Pasteboard, paraffin, aluminum, zinc, iron, copper, silver, gold, mercury and the hand are also transparent to these radiations. The only opaque bodies found were platinum of a thickness of 1 millimeter and opalescent glass 3 millimeters in thickness.

While examining the refraction of the rays by means of an aluminum lens, the author stated that this metal would store the rays in great amounts, giving them off again for more than twenty-four hours after it had been withdrawn from the source. A similar power, though of smaller intensity, was found in the case of ordinary glass; while lead, copper and pure water did not show it.

Salt water and a solution of sodium hyposulphite in water, on being submitted to the action of a source of N_1-rays, would become active themselves, acting as sources for a very long time.

When the hand is held for some time at a small distance from a source of N_1-rays or touching the latter, the hand would diminish itself the phosphorescence of the screen, this property being kept for some minutes.

N_1-rays as given off from the above sources are refracted by glass, copper and aluminum prisms and diffracted by a grating.—*Scientific American.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 15, 1904.

The Naval Strength of the United States.

By Geo. W. Melville,
Rear Admiral U. S. N.

Neither the actual nor the relative naval strength of the United States, as compared with that possessed by Continental Powers, can be measured alone by the number and character of the warships of the respective countries. While graphic charts may show the relative amount of displacement, as well as the amount and character of armor and armament possessed by the several powers, there are other factors that must be taken into consideration in determining relative strength, for the ability to keep the ships in a fighting state of efficiency is only one remove in importance from constructing them. It is because our actual naval strength is greater than that represented by the size of our fleet that our influence as a world power extends beyond our own shores.

War is now a business rather than an art or science, and therefore it is bullion and brains, as well as bullets and brawn, that must be considered by nations undertaking or contemplating hostilities.

War can no longer be indulged in by weaker countries without risking their existence as nations. An occasional revolution or insurrection is the nearest approach to war that the weaker countries can experience, for the tendency of the age, if not manifest destiny, is to make it impossible for the smaller powers to bring on a general conflict. It is like the pauper aping the millionaire for weaker countries to indulge in war. It is certain that when weaker nations imperil the balance of power, by provoking a conflict, that such action inevitably means the absorption of a weak by a stronger power.

The doom of that nation is sealed which does not possess

some foreign markets, and as this trade can only be retained when once secured by the possession of a merchant marine and a powerful navy, the question of relative naval strength is one that concerns the commercial, maritime and military interests of the country.

EFFICIENCY OF OUR WARSHIPS AND NAVAL PERSONNEL.

Our navy, though small, possesses an efficient personnel, a well-built material, and an administrative organization that is well adapted to existing needs. Our actual naval strength, however, represents more than our number of battleships built and building.

The size of the battleships, the resisting power of the armor and the character of the armament must always be regarded as important elements in determining the capabilities and possibilities of any naval fleet. The value and importance of a trained personnel should likewise be recognized in its fulness. The administrative feature is also an important element, for however efficient a navy may be for peace purposes, the safety of a nation would be impaired if the administrative organization was not of such character that would make provision for the expansion of the navy to the necessity and demands of war.

ADMINISTRATIVE ORGANIZATION AN IMPORTANT FACTOR OF NAVAL STRENGTH.

The present organization of the Navy Department is a remarkably strong and able one. The victories of both the Civil and Spanish-American wars were the outcome of the working of that splendid and developed administrative system. Its efficiency has been tested, and in reviewing the military events of the war with Spain, foreign critics have emphasized their admiration of the splendid administrative organization that we possess. The Navy and the Nation should be slow to give up an organization that is so simple that its detail work can be comprehended within a few weeks by every executive administrator upon assuming office. The country at large is also familiar with its method of doing business. The operations of the navy have been so developed that there is an admirable system of checks

and counter-checks whereby fraud and corruption are practically made impossible. The system is admirably suited to progression and advance, and the deep affection which the country possesses for the naval service is due in considerable part to the manner in which the department has been administered. It is only necessary to recall that those who have served longest as executive heads of the Navy Department have had the least desire to seek a change in its administrative organization. There has not been a single type of ship designed at the Technical Bureaus that has not rendered efficient service. The abortions in the shape of warships have been the product of those who have not had technical experience and training, and it has been against the vigorous protest of the Construction Board of the Navy that such anomalies have been constructed. The Navy Department has ever been receptive for advice and information from the military officers, and any attempt to subordinate the technical and civil features of administrative organization to that of the military will not add to our military strength.

It is, however, neither the size of our fleets, the character of our crews nor the splendid administration of affairs that constitutes these primary features of the naval strength of the United States which are most feared and respected abroad. It is the reserve of wealth, resources and manufactures, as well as the great body of men capable of being trained to naval duties, that constitutes our actual power. It is the power to remain on the firing line, rather than our ability to get there, that is best recognized by our possible foes.

The events in the Far East afford a striking illustration of the fact that it will be the reserve battalions of the contesting foes that will decide the contest. It is the lack of munitions and financial resources that has prevented war.

OUR COLLATERAL FEATURES OF NAVAL STRENGTH MOST FEARED BY EUROPE.

In determining the relative strength of naval powers, there are, therefore, collateral issues involved other than

those of displacement, gun fire, armor protection, organization and personnel.

When the United States plunged into war with Spain, the strength of the warships of the two powers was about the same, so far as graphic charts and carefully-prepared tables could show. When there was a meeting of the fleets at Santiago, three months after the declaration of war, the squadron of Spain had become weakened, due to the failure of the vessels to secure ammunition, coal, men and even food supplies. On the other hand the ships of the American fleet were probably in better condition than they were at the beginning of the year, for a fleet of auxiliaries had brought to our vessels everything that was requisite for continuing efficiency. It was the collateral rather than the military features of naval strength that eventually brought about the relative difference in strength between Cervera's and Sampson's squadron.

The showing that can be made of ships and guns possessed by the several powers as a measurement of strength is more apparent than real. It is not necessary to doubt that the vessels of any nation are of the tonnage that they are claimed to be, nor need it be denied that practically all vessels lately constructed possess modern armor and armament. The stress of war conditions, however, will soon impair the condition of the ships unless there is an ample reserve of men, money and means of various kinds.

The four factors of displacement, armor, armament and skill of personnel are regarded by many naval experts as the substantial elements of naval strength. Each of these elements is of essential importance, but there are other things to be considered. Our continental rivals are ready to acknowledge that we are upon an equality with them as regards the penetrative quality of our armament and the character of our personnel. Yet by reason of our weakness in the number of trained men, and of our lack of an adequate supply of modern guns, it is maintained abroad that we are really behind Germany in these respects. If our strength is yet feared, as it surely is, it must, therefore, be due to our superiority in what some military men regard as unimportant collateral features.

The strength of the United States, as compared with other powers, has been so often and clearly shown from the standpoint of displacement, guns and enlisted personnel that it is only necessary to state that practically all strategists place England, France and Russia ahead of us. There is a difference of opinion as to whether Germany is in advance of the United States in actual fighting ships, that is, judging from the standpoint of the strategists and tacticians. It is certain that Germany expects to leave no doubt upon the question five years from now.

As one carefully reads the views, and hears of the undercurrent of the deepest thought of Continental naval experts, he is strikingly impressed with the fact that all are coming to the opinion that in determining this question of relative strength, some factors that have heretofore been omitted now are rising to primary importance, and thus the actual relative strength of the United States is regarded as much greater than that heretofore accorded by any of the experts.

The following are some of the factors that have been given too little consideration in the past, but which are now beginning to be realized in something like their fulness.

(1) The money required to carry on the operations of a modern war. It was asserted about twenty years ago by one of the best informed generals of the British War Office that the actual cost of every soldier in time of war would approximate a guinea a day. These figures were considered astounding, but the events of the Spanish-American and the South African wars showed that the cost was rather underestimated than overestimated. There is in the conduct of war a profligacy bordering on to wanton waste that seems unavoidable. As one reviews the events that occurred in Cuba, Porto Rico and the Philippines, it would appear as if the cost of the military campaign in those countries should not have been excessive, and yet the direct and indirect expenditures of our military successes in those countries has run into the hundreds of millions of dollars. The cost of the South African war was about five times that expected by even the most pessimistic of the British experts.

Although the British and American administrative officials had reason to anticipate war, and had made preparations for years for the impending conflict, the cost was excessive. From the time the call to arms is sounded, the cost of all supplies seems to increase rapidly, at least as far as military and naval expenditures are concerned. On the one hand, there is a fear of the invader, and as a result millions of dollars are wasted upon fortifying points that could by no possibility be attacked. Vessels are purchased and used for harbor defense whose only capacity to do harm would be in the direction of killing or maiming their own crew. The expenditures in connection with the transport service are simply typical of what goes on in every direction. The cost of war has thus reached a point when but few nations can indulge in the pastime. For a time war may stimulate the general business of a nation, but the reaction soon comes, and there, then, is a decade of taxation to pay for every year of strife.

From a financial standpoint the victor of a war derives as little benefit as the vanquished. Increased burdens and responsibilities are thrown upon the conqueror, and it is doubtful if an instance can ever be shown wherein the conquering nation was not compelled shortly after the termination of the war to increase the tax rate to meet new responsibilities and liabilities. The peace of the world at large is disturbed by every war, and the nation that takes unto itself territory from its defeated foe simply invites the jealousy, if not the envy, of other powers whose trade relations have been or are presumed to be affected.

It is the wealth of England and the United States and the ability of these countries to remain for a long period at war that is the great factor in preventing them from being attacked by others. With each succeeding year the material wealth of a country becomes a greater factor in determining its military power, and therefore there should be placed as of exceeding importance in determining actual naval strength this material wealth of a nation.

(2) The manufacturing, mining and agricultural resources of a nation must be regarded as military factors of great

importance. It is as essential to be able to keep battleships in efficient condition as it is to build them, and that nation which cannot manufacture its own armor, ammunition and ordnance, as well as repair its own ships, will not count much as a sea-power. The possession of battleships by the Chinese and by some of the South American republics is not seriously considered by thoughtful naval experts, for, by reason of their lack of manufacturing resources, the battleships of such countries must soon reach the scrap heap. That nation which does not possess coal fields, as well as beds of iron and copper ore, will never be able to carry on a protracted naval war. It was but a few years ago when a Continental military expert pointed out the important part played by glass in making preparation for war. In the transportation of various acids essential for the manufacture of war material, glass is absolutely necessary. In the various laboratories of all great industries, glass is used for countless purposes, and anything which would interfere with its manufacture would be a great hindrance to the output of much war material. The value of glass as a war material is thus brought to your attention in order to show how dependent a modern army and navy is upon the manufacture of some material that seems wholly used in the arts and sciences. It requires many links in the chain that keeps moving a great army and navy, and probably every general industry is an important contributor in some indirect way to national defense.

The experience of the United States in the winter of 1902–1903 as regards the available coal supply for domestic and manufacturing purposes gave the country a great surprise as to the comparatively small amount that was or even could be kept in store. Probably no article in common use—that is, of a bulky nature—has so short a reserve supply in stock. Only a small reserve is kept on hand either at the mouth of the mine or at the transportation terminals, since every storage means at least two handlings, and each handling represents a depreciation in both quality and quantity.

For a nation contemplating or engaging in war, coal,

or the want of it, is the life or death of a fleet. The want of it was Cervera's undoing. Had he had coal, he would never have been caught at Santiago "like a rat in a hole." The nation that cannot absolutely rely upon securing for its naval and mercantile fleet an adequate supply of good fuel will not figure for any lengthy period as a sea power.

Coal is a very bulky article, and under certain conditions will deteriorate rapidly. In its transportation, there are required extensive piers, expensive machinery and a vast amount of rolling stock. It is an extremely expensive undertaking to increase the facilities for transportation of fuel, and one of the greatest difficulties that will be experienced by Great Britain in the maintenance of her great fleet upon a war footing will be the securing of an adequate supply of coal. The average daily consumption of some of the great ocean liners is as follows:

"Oceanic"	480 tons.
"Lucania"	475 "
"Deutschland"	570 "
"Kaiser Wilhelm der Grosse"	500 "
"Kaiser Wilhelm II"	600 "

Each of the great ocean liners practically requires a coal train to keep it supplied with fuel, and when these vessels are employed upon service other than between two regular terminals, the question of coal supply will be of great importance. It requires about 50,000 tons of coal to supply the actual wants of the British ships taking part in the annual manœuvers. Hundreds of thousands of tons would be required annually by any naval power undertaking war, and the problem of storing and transporting this fuel rises to one of magnitude.

By reason of our possession of the Aleutian and Hawaiian Islands, and of the great distance between Japan and our Western coast, it would be almost impossible for any nation, except England, by reason of the problem of securing sufficient coal, to assemble a powerful fleet off any of our Pacific seaports. The capture or temporary destruction of the principal coal mines of British Columbia ought not to be a difficult matter; so that the principal seaports of

Washington, Oregon and California ought to be almost immune from any probability of blockade.

Now that an isthmain canal is an assured fact, our people should awake to the realization that we have taken a world's burden upon us, whether this burden be regarded from the military or financial standpoint. The tendency to build longer, broader and deeper draft vessels will compel the scope of the canal project to be enlarged, and as a result the cost of the waterway will not be far from $400,000,000. The natural features of the country environing the canal are of such a character that in order to prevent the impairment or destruction of this great waterway, every yard in length of the canal will have to be defended both by day and night, and it is a conservative estimate that does not provide for an expenditure of another additional $300,000,000 for the erection of forts, the building of battleships, and the maintenance of an army of defense or protection. Our new conditions are giving us new responsibilities, and the building of the Panama, as compared with that of the Suez Canal, may well be likened to the respective work of building a battleship and a gunboat.

The building of the interoceanic canal is going to have an important bearing upon our relative naval strength. It will bring upon us military responsibilities and cares, and greatly add to the cost of both military and naval establishments. It may compel us to fight great naval battles in the vicinity of the Bay of Panama, for it must ever be kept in mind that the best fighting nation of South America—Chili—has not altogether been satisfied with our past treatment of her.

With the coal fields of Pennsylvania within two days' reach of the New England seaports, with the Virginia and Tennessee fuel districts within two days of the Atlantic coast, and with the Alabama coal territory within two days of the Gulf ports, our capabilities for coaling warships is exceedingly satisfactory. For defense purposes the oil fields of California ought to be available in case of necessity as a means of maintaining the fuel supply of at least a fleet of coast defense ships.

While but few of the soldiers and sailors who volunteer for war ever reach the firing line, every one of them must be fed, and this simple statement ought to tell of the part that the agricultural resources of a nation figure in the business of war. For every man in England who fears an invasion from the Continent, there are a hundred who are apprehensive as to where the food supply of Great Britain is to come from when that empire is not at peace with a strong naval power. The granaries of Australia, India and America are so remote from the British Isles that it is going to require the service of a considerable portion of the British Navy to maintain the food supply of her people at home, and, therefore, every warship and armored cruiser possessed by that nation will by no means be available for the line of battle. The various powers of the Far East have but to look threateningly at each other before there comes an order to America for breadstuffs and meats. Even the question of securing sufficient hay and oats for feeding the comparatively few animals employed in warfare becomes one for thoughtful consideration.

THE MERCHANT MARINE OF GREAT BRITAIN TAXED TO SUPPLY TRANSPORTS FOR THE SOUTH AFRICAN WAR.

In conducting the South African war, it was necessary for England to transport the greatest army ever moved for any comparable distance. There was absolutely no molestation to the movement of troops, horses and munitions, and yet her merchant marine was taxed to the utmost to provide sufficient ships. There were, of course, available, as naval auxiliaries, many mail and freight steamers plying regularly between the British and other ports of the world. The impressment of such steamers, however, by the Admiralty and War Office would have resulted in the loss of British trade and commerce that might never have been restored. In case any small naval power had espoused the cause of the Boers, this movement of troops and munitions might seriously have been interfered with. It is certain that the insurance rates of merchant vessels would have been increased to a point where the shipping trade would have been other than a profitable business to British shipowners.

THE PROTECTION OF A MERCHANT MARINE IS A MILITARY PROBLEM UNTO ITSELF.

While a merchant marine must in the main be a valuable auxiliary to naval strength, the history of the world shows that the downfall of commercial and maritime nations has been repeatedly due to the possession of such a large undefended merchant marine that this commerce invited attack and became the prey of nations possessed of efficient fighting ships.

Closely associated with the defense of the merchant marine is that of distant colonies. The average colony is probably a tax rather than a support to the home nation, and by the time any colony becomes self-supporting, then comes the agitation for either great expenditures for internal improvements or for independence. It has been the defense of the merchant marine and colonial possessions that has caused the downfall of nations at various periods.

The experience of the Italian, Portuguese, Spanish and Dutch people may be repeated in the case of every nation that places too great a value upon the possession of a merchant marine. There is a Chinese proverb which says that the junk fleet of an opposing Viceroy constitutes a hostage that will always bring him to terms. It will not, therefore, be wise to place too much reliance upon the aid that can be rendered a navy by its mercantile fleet. While England has a great navy, the question may be seriously propounded whether it is not too small rather than too large as compared with the war protection essential for its great merchant marine.

THE DIFFICULTY OF SECURING A RESERVE BODY OF MEN CAPABLE OF BEING TRAINED TO NAVAL DUTIES.

As in the case of the army, the reserve of men for naval needs must come from the country at large. It would be just as logical for the military authorities to rely upon the militia as a needful reserve for war purposes as it would be for the naval administrators to depend upon the merchant marine for supplying the reserve requisite for naval needs.

The mercantile marine of the several countries will also prove disappointing as a source of supply of men by reason of the large number of aliens serving in the ships of the leading maritime countries. The British ships contain thousands of Chinese, Japanese and Lascars, and in time of war these men will have to be replaced by British subjects, or else the laying up of some of the ships will occur.

The Danes, Swedes and Norwegians can be found in large numbers in German, American and English ships, and it will not be surprising if the national spirit of these seamen will be a determining factor in their decision as to how they will act in time of a great war. It may thus be easier to get ships than secure the necessary men to man them.

The question of securing a reserve of efficiently trained men for battleships and cruisers is one of extreme importance in modern warfare. The conditions of the hour of battle on board the war vessel are very different from the conditions existing in time of peace. There is not a naval power in the world which is not at the present time short of an adequate complement of trained men. Under cruising conditions, when only a portion of the boiler and engine power is used, when hatches are opened and when the majority of the vessels cruise in northern latitudes in summer and semi-tropical waters in winter, the health of the crews is all that is desired. The war vessel is, however, anything but a sanitarium during time of war, particularly if the ship is kept in readiness to meet anything like an equal foe. Then will come an inevitable large sick list, and unless there is a reserve of trained men to maintain the full complements of the vessels, the fighting efficiency of the ships themselves will become seriously impaired.

OUR RESERVE OF TRAINED MEN MUST POSSESS ENGINEERING INCLINATIONS AND MECHANICAL ABILITY.

It is not so much an acquiring of the habit of the sea as it is the possession of engineering inclinations that are requisite for the modern man-of-warsman. In the operation of the various mechanical appliances that are now installed on board the warship, it is a technical rather than the

nautical training that must be secured. The three great manufacturing nations—England, Germany and the United States—thus possess an inestimable military advantage in their ability to secure in time of war the reserve of men needful for naval purposes.

While the merchant marine of a nation might furnish some comparatively well-trained men in time of war for naval vessels, it must be remembered that at such time the demands of the merchant marine itself for training men greatly increases. Then again, as quite a large number of merchant vessels must be secured as auxiliaries to the fleet, it is highly improbable that all the men secured from the merchant service would be more than sufficient to man these ships. The value of the merchant marine, therefore, as a source of supply for naval needs in time of war is more apparent than real. Compared with the necessities of a nation, the carrying capacity of the merchant marine of any country can be easily taxed, and there are hundreds of tramp steamers that now traverse the various oceans that would have to seek port in case they were liable to seizure by the cruisers and scouts of a possible enemy. The fostering of a merchant marine should be looked at from a military standpoint, and those who are interested in the revival of our maritime industry would probably secure better success if more consideration was given to this phase of the problem.

The experience of the war with Spain conclusively showed that skilled mechanics, with excellent powers of observation, do not require a long period to be trained for efficient duty, either in the turret or in the engine-room. It should be recognized that the great body of men for naval needs, in case we ever get into war with a strong power, must come from the iron or metal workshops, engine-rooms and fire-rooms on shore. The capability of the artisans of different nations to adapt themselves to technical naval duties may be the real test of strength for sea power, and certainly in this respect we ought not to believe that any nation is our superior.

THE QUESTION OF TRANSPORTATION OF EXCEEDING IMPORTANCE.

The purpose of Great Britain in considering the coast line of every possible enemy as one of her military frontiers has caused the conduct of war to be more dependent upon methods of business than principles of strategy. The most difficult problem that confronted President McKinley in the management of the Spanish-American war was the devising of means to transport the troops, horses and supplies of General Shafter's army. It was likewise the problem of transporting troops and munitions of war to the Philippines that was not only the most expensive, but the most troublesome matter to be handled in insuring peace in those islands. The actual fighting was nothing as compared with the business problem. The fact that we are likely to spend several hundred million dollars in establishing peaceful conditions in the Philippines shows that the question must be regarded as a business one.

The problem of transportation was the most difficult one confronting the British Admirality and War Offices in the crushing of the Boers. It required months to assemble the necessary ships and fit them as transports for conveying an adequate number of troops to South Africa. There was comparatively little for either Lord Roberts or Kitchener to do after the transportation problem had been solved.

Where armies must march but a short distance to the field of battle, as the Germans did in 1871, the transportation question may not rise to as supreme an importance, but in the conduct of naval operations it is absolutely essential to consider the problem as a serious one. The naval power, therefore, which possesses facilities for rapid and extensive transportation of men and material, is in many respects well prepared for war.

While we may have but few ships engaged in the foreign trade, we possess a good-sized fleet of coastwise steamers, some of which could be quickly used as auxiliaries to the fleets protecting our coast.

If there is one particular advantage that we possess over our commercial rivals, it is in the economy and rapidity

with which we are able to handle material. In cranes, conveyors and engineering appliances we are in the front rank. In methods of conveyance such strides have been made that we have changed the conditions affecting the carrying of supplies, and, as a result, there has been made possible by our superiority in handling material, not only the lowest freight rates, but the quickest dispatch for long hauls. Any hostile fleet, therefore, attempting the blockade of either a Gulf or Atlantic port, will find the manufacturing resources of even the Mississippi Valley at the early command of our military and naval authorities. The possession of vast and superior transportation facilities by our military forces will make possible the building of temporary forts, and the repair of war vessels in a surprisingly short time. The cost of this hurried work may be enormous, but every continental nation recognizes the fact that in times of emergency we are ready to indulge in such an outlay, and thus the problem of blockading our coast is one of such magnitude that it is practically beyond the possibility of any single power. It is the reserve of resources rather than the line of forts, or the fleet of battleships, that will be the great deterrent for some decades, at least, to any attack from Europe. It will be the clink of the bankers' gold that will tell the tale of the battles lost or won.

OUR RESERVE OF MEANS AND MONEY A SHIELD OF DEFENSE—OUR NAVY A WEAPON OF OFFENSE.

From time immemorial the individual, as well as the nation, has been obliged to provide both a shield and a weapon for either offensive or defensive purposes. It is our agricultural, mineral, manufacturing and financial reserve, combined with our power to utilize such latent resources, that constitutes the best shield of national safety. While it is true that China may possess great wealth of agricultural and mining resources, the lack of transportation facilities in that country makes it impossible to utilize such resources for either national safety or the public good.

A great army and navy may be the only possible weapon for offensive work. If it be good military policy to make

the enemy's coast the first line of our national defense, then there should be a strengthening of both services. As wars seem inevitable, every nation should be prepared to strike the first blow. A hundred millions invested in cruisers and battleships may save the expenditure of ten times that amount in drawing upon our latent resources as a shield of defense. Our navy is not as strong as it should be, but the increase should be progressive. The naval service, however, should always keep in mind the fact that there are aggressive individuals high in authority in every naval service who are too desirous and too prone to use any weapon that is placed in their hands, and thus there is a prejudice existing against the building of a strong navy that must ever be recognized.

The demand for an increase in naval strength should best come from those without rather than from within the service. The most striking fact in connection with the rehabilitation of the American Navy has been the enthusiastic and consistent support of the people of the Middle West to an increase in naval strength. Until recently but few recruits came from that section, and the manufacturing interests between Pittsburg and Denver received but little, if any, direct financial benefit from the building of either ships, machinery or guns. Strange as it may seem, the wavering in the desire to augment our naval strength has come from the Atlantic and Pacific Coasts; the representatives from those sections at times being more desirous of having the Government engage in various internal improvements and the rehabilitation of the merchant marine than in strengthening our fleet of battleships. It is because, I believe, that the real interests of the Navy can be best subserved by pointing out the great shield that we possess in our latent resources rather than by attempting to tell of the weakness of our Navy as a weapon, that I have dwelt upon the strength of the shield rather than upon the weakness of the weapons of national strength.

THE OPPORTUNITY OF AN ENLISTED MAN RECEIVING A COMMISSION SHOULD BE INCREASED.

The best work that the Navy itself can do is to increase the efficiency of the organization. There should also be an earnest effort made to bring the Service in closer touch with the people. While the affection of the country for the Navy has progressively increased during the past ten years, there is a strong and deep feeling prevailing that the Service is too exclusive, by reason of the fact that it is not as easy for the average young man to secure a commission in the Navy as it is in the Army. Since the retirement of General Schofield from the command of the Army, nearly all the general officers of the Army, who commanded troops in the field, entered the Service as a volunteer and won their commissions by sheer merit. The military and administrative service performed by such generals as Miles, Brooke, Young and Chaffee justify the entry of young men into the regular army as commissioned officers who are other than graduates of the West Point Military Academy. The gate to a commission in the Navy should be opened wider, and I know of no better way of bringing such action about than by permitting the graduates of technological schools, who possess military aptitude and inclinations, to compete for commissions in the Service. The curricula of at least a dozen scientific schools, from a scientific standpoint, is the equal, if not the superior, of the Annapolis institution.

The work of the modern naval officer is to a great extent technical, and surely such must be the case in the junior grades. The work of the ordnance and electrical expert in both Army and Navy is not widely separated from that of the mechanical. In fact, the measure of one's success in ordnance and electrical lines is simply proportional to his technical inclinations, study and training.

OUR TECHNOLOGICAL UNIVERSITIES CAPABLE OF SUPPLEMENTING THE WORK OF THE NAVAL ACADEMY.

The question of utilizing the engineering colleges for the training of officers for the Army and Navy, and thus bringing both Services in closer touch with the people, is not a

new proposition. In writing upon this subject only a short time ago, I presented the following views, which received the cordial endorsement of General Miles, then commanding the Army, and of General Corbin, executive officials whose military experience in both the Civil and Spanish-American wars particularly qualified them for giving expression as to the capabilities of the graduates of our engineering colleges to qualify for such work:

"The Army and the Navy will require for war purposes more officers than West Point and Annapolis can supply. It is hardly possible that Congress can be induced to enlarge these schools to the size demanded by the Nation's requirements. As many competent officers must be secured for both the Army and the Navy from sources outside Annapolis and West Point, it is my belief that these military necessities can be met by calling upon the technological colleges to perform the duties which are within their power, and which in honor they are bound to undertake. In order to secure a sufficient and effective directing personnel for the Army and the Navy, it has been proposed to commission, from the graduates of the technological colleges, those young men who are able to complete successfully a course of technical and military instruction prescribed by officials of the Government.

"The military question is in many respects an engineering question. There are a hundred scientific colleges in this country which are capable of giving instruction necessary to fit their graduates for important engineering duties; and it is not unreasonable to presume that a majority of these institutions could give military instruction if substantial inducement were offered for carrying on the work. During the Civil War some of the most valuable of the naval engineer officers had been those who had been trained as civil engineers. The training of these men had been well grounded along engineering lines, and by observation and attention to duty, the work incident to a naval career soon became familiar to them.

"There are engineers in Europe, as well as in America, who are controlling and directing more employees than are

comprised in the entire personnel of the United States Navy. An engineering mind is an analyzing, directing and military mind, and it can be employed for the accomplishment of strategical and tactical movements. The rapidity with which an army corps can be moved may decide the destiny of a nation; and the success of this work, under existing conditions, is more likely to be dependent upon the superintendent of a railroad than upon a military commander. The executive ability of the managing engineers of our great industrial plants, in expeditiously furnishing munitions of war, may be of greater benefit than the enrollment of an army corps.

"The requirements of the Army and Navy as regards commissioned officers cannot be met by Annapolis and West Point. The work can be carried on only by many technological colleges of the land, under the direction of master minds acquainted with our military needs and having some knowledge of the power and influence of university work. Under the control of the Secretary of War and of the Navy, there should be efficient and thorough supervision of this scientific and military education; and the maintenance of all such educational courses should be carried on in a manner satisfactory to the Government. If this were done, it would be a step in the direction of co-ordinating American universities and colleges. It would raise the standard of the inefficient institutions by stimulating emulation and encouraging a comparative study of different methods of instruction. Scientific instruction of a high grade is already provided by numerous technical institutions in many parts of our country. The range and quality of their work have immeasurably advanced within the last few years, and several now take rank with the best institutions of their kind in the world. These colleges have made wonderful strides along educational lines, and their faculties make the proud claim that their graduates are the equals in culture and intelligence of those sent out by the colleges of liberal arts.

VIEWS OF COLLEGE PRESIDENTS AS TO THE MILITARY DUTY OF THEIR INSTITUTIONS.

"During the last ten years I have discussed this question with distinguished educators, prominent statesmen, and able military leaders, and it seems to be the general opinion that the good of the nation demands that some such action should be taken. One distinguished Southern educator declares 'such a measure would be founded upon patriotism and common sense.' The lamented General Francis A. Walker, of the Massachusetts Institute of Technology, who was very earnest in his desire to have his institution perform some military duty for the nation, in writing to me upon the subject, said: 'Whether looked at from the point of view of one interested in the political, military, or naval history of our land, the subject concerns the defense of the country.'

"At least threescore of college presidents have been consulted in regard to the general work of bringing their institution to a clearer sense of their military obligations to the State. It is practically their unanimous testimony that the work is not only in the interest of sound technical education, but that the greatest beneficiary would be the National Government. When such conservative forces are aroused to the necessity of this work, it must be manifest that it is of import to the nation. It is of marked significance that this proposition appeals most strongly to those college presidents and professors who were formerly identified with either the military or the naval service. These men, from personal experience and association, realize that mutual benefit must be secured by bringing all scientific institutions in closer touch with each other and with the military and naval authorities.

A NATIONAL COMMISSION SHOULD BE APPOINTED TO INVESTIGATE THE MILITARY POSSIBILITIES OF ENGINEERING INSTITUTIONS.

"It is, therefore, time for a plan to be formulated whereby the engineering institutions can render the important military duty to the nation that is within their power to accom-

plish, and that ought to be within their desire to perform. As it is to be expected that Congress will be more inclined to follow than to attempt to direct public sentiment upon this question, the matter must be taken in hand by the immovable sanity of military officials and scientific educators. A joint commission composed of two officers of the Army, two of the Navy, two representatives of the land-grant colleges, and two representatives of other scientific institutions, with some former Secretary of War or the Navy as chairman of the body, should be appointed. Within a year this commission could formulate a scheme whereby the scientific institutions of the United States could supplement the work of West Point and Annapolis, and whereby it would be possible to secure for the future a reserve of highly trained technical men who would receive at least the principles of a military education.

"Even to meet the issue of war with Spain we had to increase our army tenfold. It is well known that, despite the enormous advantages that we possessed over our foe, we had to keep our troops for months in camps of instruction. In fact, it took so long to work these volunteer regiments into shape that the army which besieged Santiago was practically composed of a good part of the regular army, and but few regiments of volunteers. Such delay would have been, in part, obviated if our engineering institutions had done the military duty that was within their power, and if the nation had utilized the educational forces that were within reach.

"The National and State Governments expend millions of dollars in training a volunteer force, and the primary purpose of establishing such an organization is to have in readiness at least a partly trained reserve for the needs of the nation. It is, therefore, necessary, as well as logical, to train a reserve of officers; and there seems no better way of securing this desirable result than by utilizing the great resources that are possessed by the educational institutions of the land.

"If this proposition were fully understood, it would appeal to the young men of America now receiving instruc-

tion in the several colleges of mechanic arts and sciences. These young men are strong in their own self-respect and ambition, and are intense in their love of country; and, if necessary, their conscience will impel them to offer their all for the honor of the nation. Their education should be directed so that the best within them can be brought out; and I know of no better way of training them to become noble men and valuable citizens than that they should be made to realize that they are receiving a military as well as technical and liberal education for life's work, while in the glory and strength of young manhood."

THE CALL OF THE COMING CENTURY IS FOR THE TRAINING OF THE LARGE CONTINGENT OF EXECUTIVE TECHNICAL LEADERS.

The military call of the coming century will be a demand for the elect of those trained to executive-technical work to qualify themselves so that when the call to arms comes they may be fitted to assume military responsibilities.

The nation has increased sixfold since the establishment of West Point, and threefold since the organization of the Naval Academy, and it will act as a spur and incentive to both institutions to have their work shown up with the best of the technological institutions.

Instead of calling upon all young men of the country to perform military service as in the case of some continental countries, it should be our aim to compel every technological institution receiving direct or indirect national aid to perform the service of training leaders for the military necessities of the future. Where there is an abundance of leaders, there will be no difficulty in increasing the army greatly without, to a great extent, impairing efficiency.

THE DESTINY OF EVENTS WILL COMPEL US TO EXERCISE PARAMOUNT RIGHTS IN CERTAIN WATERS.

It may be that this nation may be free from war for many years, but where a nation asserts certain doctrines that interfere with the colonization projects or commercial rights of rival powers, the maintenance of such doctrine

can only be done at times by force of arms. From time immemorial nations have asserted paramount rights over adjoining buffer states, over environing seas, and our entrance as a world power has made it necessary for us to protect domains beyond our own coast. Force of circumstances will compel us to assert a paramount right in the West Indies and the North Pacific. We must either build a navy capable of maintaining this claim, or else sacrifice foreign trade that is a necessity to the disposal of our surplus agricultural and manufactured products.

The fisheries and gold deposits of Alaska and Aleutian Islands will compel this nation, at a very early day, to reassert the claim that Behring Sea is a closed ocean, and that we have and will exercise a paramount right in regulating the traffic of the commerce of that body of water. The following views, although expressed upon the subject of an interoceanic canal, are exceedingly applicable to the policy that should be formulated in regard to our position of the Pacific.

"The Pacific Ocean is an expanse of magnificent distances. Neither over the lands of any empire, nor over the 'barren foam' of any other sea, can one traverse so many leagues without crossing the border, as upon its waters. Its area is two-fifths that of the whole surface of the globe, and more than two and one-third times that of the Atlantic, with all its tributary seas. In the distribution of the land within its limits, the Pacific presents marked contrasts. Its southwestern area is a vast and tangled cluster of islets, islands, and archipelagoes, culminating in continental Australia; its eastern and northern portions are but an ocean desert, 'where gloom the dark, broad seas' alone, save for such fair oases as Hawaii.

"Conquest, treaty and an imperial purchase have given the United States a position, clearly paramount, on the Northern Pacific. The boundaries of the Republic reach so far across these waters that, between eastern Maine at one extremity to the farthest of the Aleutians at other, as measured by longitude, the geographical center of its territory lies westward of the Golden Gate. The Pacific States have

a seaboard equal to that of the Gulf, and but one-tenth less than that of the Atlantic, while Alaska and the islands have a coast line more than eight-tenths that of all these three combined.

"From the southern limit of California, at 32° 28′ north, this ocean is, on its eastern and northern sides, bounded by American territory, continental or islandic, unbroken save by the short link of British Columbian coast, and reaching through nearly three-fourths the longitude from California to Japan.

"It would seem, then, that the North Pacific is, in effect, an American ocean, and that the United States should hold, in Nature's fee simple, the title to a sphere of influence there, to a paramount control. This right is not tangible in law, nor recognizable by treaty, but it is yet inherent through the possession of an imperial territory which bounds, almost wholly, these northern waters, which looks to them for commercial outlet, and which from them is susceptible of attack in war."

RADIUM AND TERRESTRIAL HEAT.

Professor Rutherford, of McGill University, Montreal, in a lecture before the Royal Institution in London, has advanced the striking theory that the earth's heat is not attributable to a molten mass that has been slowly cooling for a million years, which has been the generally accepted theory, but to the presence of radium. Professor Rutherford's address was listened to by a distinguished audience, including Lord Kelvin, Lord Rayleigh, Professor Dewar and other great scientists. Professor Rutherford was the first to measure the mass and velocity of the electrons of radium. He announced the probability of radium being contained in all matter.—*Electrical World.*

BRAKE EFFICIENCY ON MOTOR CARS.

The results of some trials made by the French Automobile Club to ascertain the distances at which motor cars can be stopped when running at various speeds are likely to upset the popular impressions formed by many motorists that a car can be brought to a standstill in its own length from a speed of 30 miles an hour. The trials in question were conducted in the Bois de Boulogne, and while they show that motor cars can stop quicker than horses, yet they required a distance of 10 feet in which to come to rest when traveling at a speed of 7½ miles an hour. At a speed of 10 miles an hour they stopped in 13½ feet, and at 12½ miles, in 16¼ feet. At 16 miles an hour, 33⅓ feet were required to stop in, and 60 feet at a speed of 25 miles an hour.—*Scientific American Supplement.*

Taylor's Absorption Process for Butter-Making.

[*Being the Report of the Committee on Science and the Arts on the invention of Charles M. Taylor, Jr.*
Sub-Committee: Samuel P. Sadtler, Chairman, F. A. Genth, Edward Woolman, George Malony.]

[No. 2276.]

The Franklin Institute of the State of Pennsylvania, acting through its Committee on Science and the Arts, investigating the merits of Taylor's Butter-Making Process, reports as follows:

The Taylor butter process, which has been been brought before the Science and Arts Committee of the Franklin Institute for examination, is a process for effecting by simple and inexpensive means, the rapid separation of the fatty particles of a sweet cream from the watery solution of the proteids, sugar and inorganic salts.

For this process, the invention of Mr. Charles M. Taylor, Jr., of Philadelphia, both United States and foreign patents, including English, French, German and Canadian patents, have been granted.

The principle upon which the invention of Mr. Taylor is based is the absorption by sheets of blotting-paper of the watery liquid, while the fatty particles remain upon the surface. After a sufficient length of time has elapsed, the fatty layer can be rolled together, separating quite readily from the moist blotting-pad. Mr. Taylor has, after much experimenting, found that heavy white sheets of blotting paper, supported upon absorptive material like Turkish toweling, placed in shallow pans, furnish the best material for use with his process.

His procedure is outlined in the words of his letter of application:

"Sweet cream is poured in through these absorptive paper separators, which are permeable to the watery constituents of the cream, but impervious to the butter-fat and solids, which form in a layer about one-quarter inch thick

on the surface of the paper. The absorptive pads, which are in contact with the paper, take up, by capillary attraction, most of the caseous and watery constituents.

"The cream may be placed in the refrigerator over night, and in the morning the butter is ready to roll off the paper. The butter may be used fresh without working, or can be salted to taste and worked like ordinary churned butter. The time of absorption requires about from three to four hours."

The advantages claimed for this invention by the patentee are:

(1) Less labor than churning, the chief work being the washing of the absorptive pads. These pads will last six months or longer in daily use.

(2) No expert knowledge is required in ripening the cream, as sweet cream only is used, thereby securing a pure, sweet butter equal to the best cream butter made.

(3) A much larger percentage of butter can be made from the same quantity and quality of cream than by churning, experiments showing this increase to be from three to ten per cent.

(4) When salted, the keeping qualities of this butter are excellent, and it will remain sweet a week longer.

(5) Families can make their own butter daily, and rest assured that they are not using oleomargarine or renovated butter.

(6) Farmers who now sell their milk at 3 cents a quart can convert the cream into butter at a large profit.

The Committee, after seeing the process carried out by the inventor and examining and analyzing the samples of the separated fatty layer, and of the butter made from this by working out the buttermilk and salting, have come to the following conclusions:

First.—The process is a very neat and efficient mode of separating the fatty portions of cream from the watery portions. Analysis of this fatty layer showed: Fat, 79.49 per cent., and casein, 2.55 per cent.

The fat percentage here is higher than obtainable by the centrifugal separator, although the casein percentage is not better than with centrifugated cream.

Second.—This separated fatty layer, if taken for immediate table use, is very palatable in taste. It does not keep satisfactorily, however, for any length of time unless the watery solution of casein is worked out of it by kneading, and the resultant butter salted. Analysis of the kneaded or worked butter made by Mr. Taylor showed: Fat, 82.95 per cent. and casein, 1.15 per cent., which indicates a distinct improvement over the raw fatty layer which had not been worked.

Third.—The product of the blotting-pad absorption is therefore not a true or normal butter as yet, because of the high percentage of casein still present; and the consequent lack of keeping quality. It seems to stand in composition intermediate between a Devonshire clotted cream and a true worked butter.

Fourth.—The product when finished by working or kneading is of a high degree of purity. In the finished sample analyzed, the Reichert-Meissl value was found to be 30.31, which is equal to the best found in any butter. It is therefore not to be classed with such products as butterine, or renovated butter, but is a true butter answering all tests and coming up to the best standards.

The Franklin Institute accordingly recommends the award of the John Scott Legacy Medal and Premium to Charles M. Taylor, Jr., in recognition of the merits of this invention.

Attest: WM. H. WAHL, *Secretary.*

Notes and Comments.

TEMPERING COPPER OR COPPER ALLOYS.

The process of tempering copper or its alloys described in the *Zeitschrift für Werkzeugmaschinen und Werkzeuge* (Journal for Machine Tools and Tools) consists in heating the metals in question for a time at the requisite temperature, sprinkling them while in a heated condition with sulphur, and then plunging them hot into a bath of blue vitrol. It is advisable to reheat the metal before it has become quite cool. Numerous experiments have shown that the new tempering process is specially suitable for alloys of copper, and that remarkably good results can be obtained by treating an alloy of copper and tin by the process just described. Any of the various alloys of

copper can, however, be used, the choice depending of course upon the nature of the article for which it is intended. The copper or alloy is usually put into the required shape (e. g., a wheel or tool) before tempering. The castings are then heated for a suitable time, say three minutes, over a fire, preferably a charcoal fire, at the proper temperature. The best results are obtained when the temperature is raised to the melting point of tin. The articles are placed on the fire and, together with the neighboring blocks of charcoal, sprinkled with powdered sulphur, till they are entirely covered by it, the sulphur-vapor thus being brought into contact with the castings. It is best to add the sulphur when the articles are thoroughly heated. After being covered with the sulphur the castings remain in the fire for a time; they are then plunged hot into a solution of blue vitriol, and allowed to remain in it for a short period. When the castings are taken from the vitriol, it is well to reheat them, and allow them to cool without the intervention of a cooling mixture. The new method of treating copper and its various alloys produces a remarkable hardness without impairing the ductility of the metal, thus rendering it specially useful for purposes for which a high degree of hardness and, at the same time malleability, ductility and toughness are required.—*Scientific American Supplement.*

ELECTROLYTIC METHOD OF ESTIMATING GOLD.

At a recent meeting of the Faraday Society, Dr. F. M. Perkins and Mr. W. C. Prebble gave the results of researches to arrive at an electrolytic method of estimating gold which should be perfectly accurate, and yet far more rapid than the ordinary double cyanide method which the authors, differing from Classen, consider inordinately long, even in hot solutions. Solutions of sodium thiosulphate, cyanide, sodium sulphide, potassium thiocyanate and ammonium thiocyanate were all tried and the results compared. The first-named was useless; of the others—which are all accurate—the thiocyanates gave the best results and the ammonium salt was better than the potassium. With currents of 0·2 ampere per square decimeter, the deposition of 0·05 to 0·08 gram of gold was complete in five or six hours. With a current of 0·4 to 0·5 ampere, 1·5 to 2 hours sufficed. The presence of a little persulphate considerably reduced the voltage required. Experiments were also made to determine the best method of removing the deposited gold. Chlorine or bromine water was satisfactory, but slow; aqua regia was risky; the authors recommended a 2 per cent. solution of potassium cyanide containing a little hydrogen peroxide or a persulphate. One or two minutes then sufficed to remove the gold.—*Scientific American.*

CENSUS OF THE FLUORSPAR INDUSTRY.

The mining of fluorspar has increased over 500 per cent. during the past decade, owing to the greater use of this mineral in metallurgical processes, especially in the iron industry, according to a special report compiled for the Twelfth Census, soon to be published. The first statistics of production were collected at the Eleventh Census, and these are compared with the statistics for 1902 in the following table:

	1902.	1889.
Quantity, short tons	48,818	9,500
Value	$275,682	$45,855

Of the twenty-two mines in 1902, fourteen were in Kentucky, five in Illinois, two in Arizona and one in Tennessee. In these twelve years Illinois, which was the only State producing fluorspar commercially in 1889, has increased its production from 9,500 to 18,860 tons.

In the fluorspar deposits of Illinois and Kentucky there is known to be a very large supply of this mineral, capable of meeting the demand for many years. As this overcomes one of the objections often advanced against using fluorspar in the smelting of iron—namely, that a constant supply of this mineral could not be depended upon—its use for this purpose should now increase rapidly. Thus far the larger proportion of the fluorspar mined has been used in steel works. Very little is used in blast furnaces or in the smelting of copper or other metals; for these purposes, and also in foundry work, its use will undoubtedly increase rapidly when its value as a flux is more thoroughly understood.

The average value per ton has varied from $4 to $8. The average was exceptionally high in the years 1896 to 1898, inclusive, reaching $8.21 in 1898. In 1902 it was $5.66; the prices reported for that year varied from $2.86 to $11.50 per ton, this higher value being obtained for the fluorspar mined in Arizona, which was used in California.—*Iron Age.*

PROCESS FOR HARDENING IRON.

A new process for hardening iron has been developed by two Prussian inventors, according to the *Engineer.* It consists in adding to iron a small percentage of phosphorus combined with a large amount of carbon. The iron is heated in a tempering powder consisting of bone dust, to which are added 300 grains of yellow prussiate, 250 grains of cyanide of potassium and 400 grains of phosphorus. The receptacle is closed and luted with clay, and raised to a clear red or white heat. The material treated is then taken out and plunged, while still hot, into a warm bath. It is claimed that this will harden the surface of a piece of iron weighing 400 pounds to a depth of about 0·04 inch, and that the iron can neither be cut nor chipped by the best steel used, and that it can be readily welded.

A CHANGE IN BRITISH PATENT LAWS.

A radical change in the granting of patents will go into effect in Great Britain on the first day of next year. The British patent laws as they now stand have been very unsatisfactory to both inventors and the public, because a patent has always been granted at the risk of the applicant, without any efficient search being made into the originality of the alleged invention. Complaint was made that patents which had absolutely no right to exist were too frequently used for the purpose of levying blackmail on manufacturers and others interested in goods manufactured under patents which were valid. The inventor has been given no warning whatever that his supposed invention was in reality no invention at all. Naturally a patent had much less value

under such a system than it would have under the patent laws of the United States, Germany and some other countries. As a consequence of repeated complaint, the British Board of Trade appointed a commission made up of eminent men to investigate the question, and as a result the patent law of 1902 was passed. The important clause relating to examinations was not made immediately operative for various reasons of expediency, but now the Board of Trade has set the approaching January 1 as the date of the beginning of a new order of things in the British patent office.

The commission did not look with entire favor upon the American system, the principal objection being that too much power is given the patent examiner, who has to act as both advocate and judge, as the *Engineer* puts it. Too much is placed on the judgment of this one man. Another defect brought out was that no intimation is given the applicant of the extent of the examination, and the search must of necessity be imperfectly carried out. Consequently a sort of compromise was selected as the best system to be applied in Great Britain.

Under this new law the British patent office cannot refuse to grant a patent, but it can so label it that it will be apparent to all that the idea in question lacks originality. It will be the duty of the office to make an investigation for the purpose of ascertaining whether the invention claimed in any complete specification has been claimed or described in the specification of any British patent within the fifty years next before the date of the application. It will thus be seen that the scope of the search is strictly defined, but this search is to be thoroughly made, so that any one who afterward desires to continue the investigation may begin where the patent office left off. In most cases the fifty years will be sufficient, for the present, at least. Ten or twenty years from now it will probably be necessary to extend the scope of the examination to sixty or seventy years, or it may be extended in a few years to make the search more thorough, dating back from the present year as the basis. No power of refusal is given under the act. But when any prior specification is found which appears to anticipate the applicant's invention, it will be the duty of the comptroller of the patent office to inform him of the objection and to give him the opportunity to amend his application so as to make it clear that he is not seeking to claim what is not new. And then, and here comes the protection to the public, unless the objection be removed it is the duty of the comptroller to decide "whether a reference to any, and if so what, prior specifications ought to be made by way of notice to the public." In other words, the duty of the comptroller will be to bring out in the patent itself the fact that the invention, so called, is not really an invention at all. The specification will bear on its face what has gone before, which will protect the legitimate inventor from the tricks of those who would use the patent office to further dishonest schemes.—*Iron Age.*

MUNICIPAL STEAM-HEATING IN DRESDEN.

An interesting application of the steam-heating system so extensively adopted in this country is in course of experiment in Dresden. In that city the Saxon Government has established a huge central station, and from this the heat is distributed among a number of the municipal buildings, including

the Royal Opera House, the Picture Gallery, Zwinger Museum, the Hofkirche, and Royal Palace. The edifices are all situated near the central heating station, which stands upon the banks of the river Elbe, whereby an adequate supply of water is always available. The station contains ten generators, producing over 55,000 pounds of steam per hour. The steam is distributed to the various public buildings by means of steam pipes laid beneath the streets. But this ingenious heating system is also utilized to fulfil a dual purpose—the generating of electricity for lighting the various edifices. The heat is generated and distributed during the early morning, when the electric supply is not required, and once the buildings are thoroughly heated, it requires but very little pressure to maintain the temperature desired throughout the day. Consequently, this arrangement enables the steam power generated during the later part of the day to drive the electric installation and maintain the pressure required. This combined heating and electric-lighting system has proved highly successful and economical, and its extension to other towns in Saxony is contemplated.—*Scientific American.*

BAMBOO.

The word bamboo suggests to most Americans a faithful fishing-rod or a dainty fan. To the Japanese and Chinese, who are the most practical agriculturists in the world, it is as indispensable as the white pine to the American farmer. They are not only dependent upon it for much of their building material, but make their ropes, mats, kitchen utensils and innumerable other articles out of it. There are many varieties of the bamboo plant, from the species which is woven into mats to the tall bamboo tree which the Chinaman uses for the mast of his large boat. One variety is cultivated as a vegetable, and the young shoots eaten like asparagus, or they may be salted, pickled, or preserved. The rapidity of growth of the bamboo is perhaps its most wonderful characteristic. There are actual records of a bamboo growing 3 feet in a single day, or at the rate of 1½ inches an hour. Varieties of bamboo are found everywhere in Japan, even where there are heavy falls of snow in winter. It is a popular misconception that bamboos grow only in the tropics. Japan is a land of bamboos, and yet where these plants grow it is not so warm in winter as it is in California Some of these varieties could be grown commercially in the United States.—*David G. Fairchild in the National Geographic Magazine.*

STEEL CHIMNEYS.

W. W. Christie, in the *Engineering News*, reports the following as among the high steel chimneys in the United States: Nichols Chemical Company, Brooklyn, N. Y., 310 feet high, 35 feet in diameter at base, 12 feet at top; Pennsylvania Salt Company, Natrona, Pa., 225 feet high, 10 feet flue diameter; Maryland Steel Company, Sparrow's Point, Md., two chimneys, each 225 feet high and 13 feet inside diameter. It is noteworthy that all these are at metallurgical plants. Also, the highest two brick chimneys are at metallurgical plants; the old Grant smelter at Denver, Colo., and the works of the Orford Copper Company at Constable Hook, New York Harbor, each of these being about 350 feet in height.

SIEMENS & HALSKE ELECTROLYTIC PROCESS FOR COPPER.

The Siemens & Halske process of copper extraction consists in leaching finely pulverized, roasted ore at 90° C. with ferric sulphate solution, containing free sulphuric acid. The ferric sulphate is reduced to ferrous, and copper is dissolved as sulphate. Electrolysis of the solution in a diaphragm cell gives copper at the cathode, and oxidizes ferrous sulphate to ferric at the anode. This is an old process, having been described in British patents 14,033 of 1886, and 3,533 of 1889. M. DeK. Thompson, Jr., has studied the reactions (*Electrochemical Industry*, 1904, II, pp. 225–231). Raw copper pyrite is not appreciably attacked by ferric sulphate, but after roasting is readily soluble. Copper can be deposited from an acid solution of ferrous and copper sulphates until the concentration reaches a low value; that is, with a current density of ·47 amperes per 100 square centimeters until the concentration of copper in solution is ·5 per cent., at which point spongy copper begins to form. Using carbon electrodes, the oxidation at the anode is at first very efficient, but as the concentration of ferrous sulphate decreases the process gradually falls off in efficiency.

Book Notices.

Machine Design. Part I: Fastenings. By William Ledyard Cathcart, Adj. Prof. Mechanical Engineering, Columbia University, M. Am. Soc. M. E., etc. (Large 8vo, pp. xi + 285.) New York: D. Van Nostrand & Co. 1903. (Price, $5.00.)

This work has been designed by the author to present in concise form, for the use of the student and designer, modern American data based upon the best practice in the branch of machine design to which it refers.

The subjects treated are arranged under the following chapter heads: Shrinkage and Pressure Joints; Screw Fastenings; Riveted Joints (Theory and Formulæ); Riveted Joints (Tests and Data from Practice); Key Joints; Pin Joints. The text is supplemented by no less than 77 tables.

The theoretical treatment of the subject has not been neglected.

The author has apparently thoroughly modernized his work, bringing the consideration of the subjects discussed up to date. In this respect the chapter on Screw Fastenings is noteworthy.

The work is fully illustrated and well printed. W.

Le Droit International, les Principes, les Théories, les Faits. Par Ernest Nys, Conseiller à la Cour d' Appel, Professeur à l'Université de Bruxelles. Bruxelles: Alfred Castaigne. Paris: Albert Fontemoing. 1904.

The last chapter of this valuable book is entitled "Le Domaine Aérien," and in it Judge Nys ably deals with the prospective application of International Law to the right of nations to the air above their countries. The development of aërial navigation, of flying machines and dirigible balloons, may be expected to bring to the fore in the future the question as to whether, as is generally held now, the rights of a State stop overhead at the distance of a cannon-shot from the ground, or whether, as seems most just, these rights extend indefinitely into space. E. S. B.

Improved Machinery, Apparatus and Processes.

[This department will contain from month to month descriptions of new machines, apparatus and processes. The data, for which the editor must depend largely on information derived from interested sources, will be carefully edited. The Committee disclaims responsibility.—The Committee on Publications.]

AN IMPROVED DUPLICATOR.

The apparatus and method described herewith are claimed to afford an exceptionally convenient and cleanly process for duplicating letters and typewritten matter, reproducing these in black ink so faithfully that the copy can hardly be distinguished from the original.

The apparatus, which is shown in the accompanying cut, contains 5½ yards of rolled printing surface, which can be used repeatedly for making duplicates.

The manipulation of the device is quite simple. The coated paper is wound upon two cylindrical rolls, and is brought to suitable tension for use by operating the hand-gear shown in the picture. The original is written, with a special ink supplied by the manufacturers, on a hard, smooth, ledger paper. For typewriting, they furnish a purple duplicator ribbon, which is said to be excellently adapted both for duplicating and correspondence. The reproductions, it is said, can be made on any kind of paper; the smoother this is, however, the better the result.

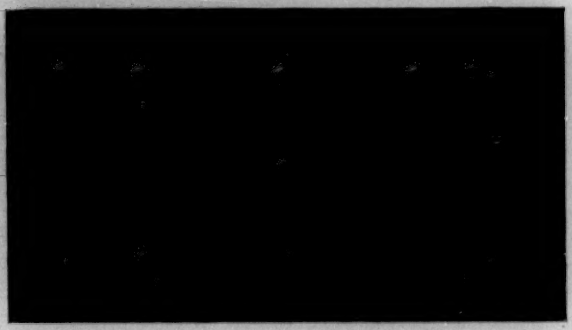
The operation is as follows: The original, when dry, is laid face down on the printing surface, gently smoothed down by hand, and left to adhere for about two minutes. This produces the negative. On the negative thus produced, the sheets to be printed are immediately and successively placed, and the impression is taken by passing gently over the sheet with a rubber roller. As rapidly as the impression is made, the sheet is removed and a clean sheet substituted until the desired number of copies (100 to 150) is made.

After the desired lot of copies is made, the printing surface is rolled to right or left, so that a fresh printing surface will be presented. No washing is required. The old ink of previous negatives will be entirely absorbed in a few days, and, although visible, will not interfere with making a clean copy from another original. Thus, the same roll of 5½

yards of printing surface, the manufacturers state, can be used from five to ten times over and over again, before becoming so saturated as to interfere with the production of clean copies. All needful supplies are furnished with the apparatus, and can be renewed as may be necessary. The Felix F. Daus Duplicator Company, 111 John Street, New York, are the manufacturers.

IMPROVED INDENTATION TESTING MACHINE.

For various purposes it is absolutely necessary to have an exactly uniform material as regards some of its physical properties, and thus the Bureau of Engraving at Washington, D. C., noted a lack of uniform



hardness in steel plates which is so essential in the use of their engravers' plates.

On these plates under discussion the original impression is made; then from them it is transferred to the steel rollers from which the final engraving plates are made. It can thus be seen how important it is that the plate be of uniform hardness, both to the engraver and the prolonging of the life of the plate, and the uniform character of the engravings.

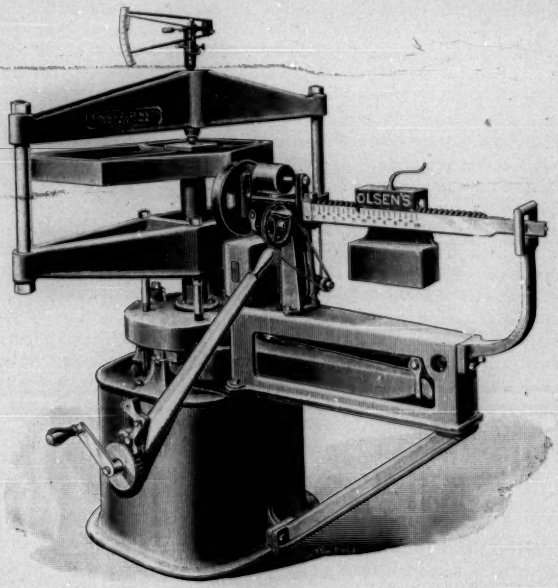
This state of affairs was presented to Tinius Olsen & Co., Philadelphia, Pa., and the task was left to them to devise a means of testing the plates for their uniformity. Various tools were tried to secure the best means of obtaining a positive and unvarying form of indentation.

Owing to the temper and quality of the plates, all tools failed with the exception of a "Standard Steel Ball." This accomplished the

indentation satisfactorily, and in case of wear or break could readily be replaced.

A portion of an engraver's plate was then tested by this means, and with the identical pressure a marked difference in the depth of the indentation was observed and is here illustrated by cut of plate so tested.

This great variation was much more than had been anticipated, and so an indentation machine was designed by Tinius Olsen & Co. and



adopted by the Bureau of Engraving. This machine is shown by the accompanying cut and will be understood from the following description.

The machine was designed and constructed so as to cover in the best possible manner the three points in question: First, application of pressure to material tested; second, weighing of pressure applied; third, depth of indentation in the material.

The pressure is applied by a hand-lever and ratchet, seen in illustration, which operates the four-screw mechanism so well known in this type of machine.

The load applied to the specimen is transmitted by a series of levers to, and weighed on, the dial vernier beam as shown.

The plate to be tested is placed between the intermediate platen shown and the compression head situated at the top of the machine, and is capable of operating on a full-size engraver's plate. On this upper head is secured the instrument for measuring the depth of indentation. This instrument is connected firmly to the machine and measures the indentation to the 1-10,000 part of an inch, recording the same automatically as the pressure is applied to the specimen.

A 3-8 inch steel ball was found most suited and was adopted as the standard tool for all indentation tests. The ball is fitted to the instrument and can easily be removed and replaced in case of wear or breakage.

To test plates in this machine two methods may be used, by keeping either the pressure or the depth of indentation a constant factor. The first method is the preferable one and has been used thus far in all tests.

A set of very interesting curves can then be plotted showing the extent of the soft spots, and from their position in the plates their cause might be determined and obviated.

A machine of this kind is now being built for the laboratory of Tinius Olsen & Co., so that commercial tests of this character can in the future be made in connection with other tests of material. A series of tests is also to be made on material for determining the results of different methods of tempering as well as results for the hardness of different metals. The latter appears to be quite an important item and important results are expected. An endeavor will be made to compare these results with those obtained on the same material in other tests, to determine whether there is a relation between the results of the hardness test and other tests now in use.